

TÍTOL / TÍTULO/ TITLE

**Smart-RBAC: A Location-based Access Control
Model for Location-specific Content Delivery and
Analytics in a Smart Campus**

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Resum / Resumen/ Abstract:

Generally, smart campus applications do not consider the role of the user with his/her position in a university environment, consequently irrelevant information is delivered to the users. This dissertation proposes a location-based access control model, named Smart-RBAC, extending the functionality of Role-based Access Control Model (RBAC) by including user's location as the contextual attribute, to solve the aforementioned problem. Smart-RBAC model is designed with a focus on content delivery to the user in order to offer a feasible level of flexibility, which was missing in the existing location-based access control models. An instance of the model, derived from Liferay's RBAC, is implemented by creating a portal application to test and validate the Smart-RBAC model. Additionally, portlet-based applications are developed to assess the suitability of the model in a smart campus environment. The evaluation of the model, based on a popular theoretical framework, demonstrates the model's capability to achieve some security goals like "Dynamic Separation of Duty" and "Accountability". We believe that the Smart-RBAC model will improve the existing smart campus applications since it utilizes both, role and location of the user, to deliver content.

Paraules clau / Palabras clave/ Key words: Smart Campus Applications, Role-based Access Control Model, Location-based Access Control Model, Liferay's RBAC Portal Application, Portlet-based Application, Dynamic Separation of Duty, Accountability, University Environment, Content Delivery, Smart-RBAC, Security Goals

Masters Program in **Geospatial Technologies**



Smart-RBAC: A Location-based Access Control Model for Location-specific Content Delivery and Analytics in a Smart Campus

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Abstract

Generally, smart campus applications do not consider the role of the user in a university environment, consequently irrelevant information is delivered to the users. This dissertation proposes a location-based access control model, named Smart-RBAC, extending the functionality of Role-based Access Control Model (RBAC) by including user's location as the contextual attribute, to solve the aforementioned problem. Smart-RBAC model is designed with a focus on content delivery to the user in order to offer a feasible level of flexibility, which was missing in the existing location-based access control models. An instance of the model, derived from Liferay's RBAC, is implemented by creating a portal application to test and validate the Smart-RBAC model. Additionally, portlet-based applications are developed to assess the suitability of the model in a smart campus environment. The evaluation of the model, based on a popular theoretical framework, demonstrates the model's capability to achieve some security goals like "Dynamic Separation of Duty" and "Accountability". We believe that the Smart-RBAC model will improve the existing smart campus applications since it utilizes both, role and location of the user, to deliver content.

KEYWORDS

Smart Campus Applications

Role-based Access Control Model

Location-based Access Control Model

Liferay's RBAC

Portal Application

Portlet-based Application

Dynamic Separation of Duty

Accountability

University Environment

Content Delivery

Smart-RBAC model

Security Goals

ACRONYMS

ACL – Access Control List

AJAX – Asynchronous JavaScript and XML

API – Application Programming Interface

CD – Biblioteca

CSS – Cascading Style Sheet

DAC – Discretionary Access Control

DB - Pavelló poliesportiu

GG - Àgora-Galeria comercial i de serveis

GIS – Geographic Information Systems

GPS – Global Positioning System

GUI – Graphical User Interface

JA - Facultat de Ciències Jurídiques i Econòmiques - Bloc A

JS – JavaScript

JSP – Java Server Pages

OGC – Open Geospatial Consortium

RBAC – Role-based Access Control Model

REST- Representational State Transfer Protocol

SDSD – Spatial Dynamic Separation of Duty

SQL – Sequential Query Language

SRBAC – Spatial Role-based Access Control Model

SSSD – Spatial Static Separation of Duty

TD - ESTCE Mòdul Docent

UB – Espaitec 2

UJI – University Jaume I

WPS – WiFi Positioning System

XML – Extensible Markup Language

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1 Introduction

1.1 Overview

Delegating the benefits of advances in technology to the end user requires constant effort from the scientific community. Smart Campus[1] applications are such efforts to employ the technical advancements to the needs of university students and staff. A typical Smart Campus application empowers the user with spatial knowledge of the university campus. Smart Campus applications usually cater to all users in the same manner, irrespective of their role in the university. However, some of the information provided by the application may not be useful to some users of the university. For example, a professor in the geology department does not need the information about the examinations conducted in economics building. Likewise, information useful for a student might not be relevant for the maintenance staff of the university. Therefore, there is a requirement to segregate information delivered by the smart campus application based on the role of the user in the university.

Smart Campus applications generally host a multitude of location-based services that deliver content based on the user's physical location. However, these services, as mentioned above, do not relegate the information based on the type/role of the user. Implementing the requirement of modeling different user roles and their relations for delivering information based on user's location improves the functionality of the smart campus applications.

In this thesis, we attempt to propose a model that can fulfill the aforementioned requirements. The proposed model extends the Role-based Access Control model (RBAC)[2] to accommodate the location component, thus belongs to the class of location-based access control models. In addition, we derive an instance of the proposed model extending Liferay¹'s RBAC [3]. The derived model is implemented

¹ www.liferay.com [accessed Jan 28th, 2015]

in a portal application, hosted on Liferay¹ Portal server. Liferay¹ portal tool, a widely popular open source portal solution for enterprises was chosen as it majorly focuses on content management and offers different applications like wiki[4], message boards[5], polls [6],etc. We developed several applications to validate the benefits of the proposed model like “Customized Smart Campus”, “Customized Liferay Built-in Applications” and “Location Analytics Application”. Additionally, location-specific web content is displayed based on the user role in the university. To evaluate the proposed model, we test the “extent of achievement of goals” of a location-based access control model [7].

Though, similar location-based access control models are proposed in the past, they are mostly concerned about enhancing the security features of an application. The model proposed in this thesis, focuses on the delivery of the content according to user role and location. Nevertheless, some of the security features are maintained in the proposed model like “Separation of Duty”, “accountability”, etc.

1.2 Motivation

With the increasing amounts of data being created around the world, there is a need to expose relevant information to the end user. Delivering content specific to the user’s location according to his/her preferences and role is a popular method for abstraction of information for the end user. However, User Specific location-based content delivery is yet to be implemented on a large scale in the academic institutions and universities around the world. Even in some of the smart campus applications of universities, the location-specific information is not shown according to the user’s role in the organization. For example, Smart campus UJI [8] delivers the same content behavior for all the requests irrespective of the user type. For example, a visitor of the campus of University Jaume I [9] may not need all the layers that are currently shown in the smart campus map, like energy consumption information of each building and electricity meter location, etc. (See figure 1)

There were many applications created in a university context for the students alone to service location-specific data based on the contextual information [10]. For example, in [10], when a student passes through a library, content with respect to the book will be notified. However, to identify whether the user is a student or another entity in the university requires the implementation of security policy like access control systems.

One of the popular access control models, Role-based Access control (RBAC) [2] is being used in many sectors due to the simplicity of the concept of “Role”. A role acts as a middle layer between the user and the permissions needed by the user to access a particular resource. Extensive research is being carried out for integrating location component in an RBAC for improving the security of smart applications. This was the motivation to design a location-based access control model on top of an open source role-based access control model.

The reason for choosing a Role-based Access Control (RBAC) model [2] for the smart campus environment is the enterprise-like structure of universities. According to [11], a university can be viewed as an enterprise. University, similar to enterprise, consists of main user types with different requirements. RBAC can easily cater to the requirements of the university by providing roles along with hierarchy.

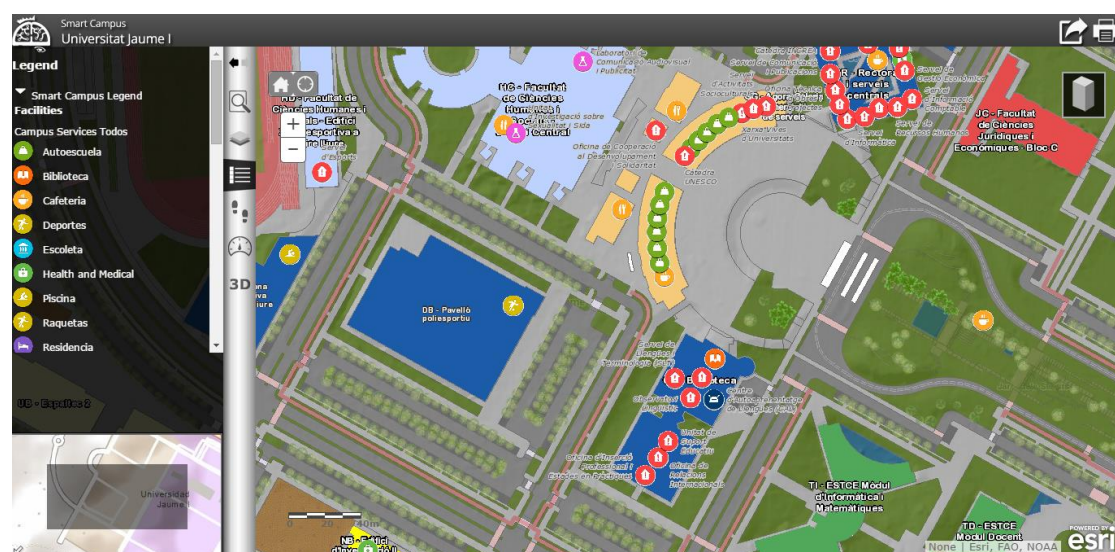


Figure 1: A screenshot of Smart Campus UI [8]

1.3 Objectives

The main objectives of the Master thesis are to:

- a. Propose a location-based access control model, Smart-RBAC to deliver location-specific content relevant to different types of users in a university environment that achieves the security goals like separation of duty and accountability.
- b. Create a prototype portal application based on Liferay¹, with a derivative of Smart-RBAC model that extends Liferay¹'s Role-based Access Control (RBAC) model. Test and validate the proposed model for the University Jaume I campus users.
- c. Develop and customize portlet-based applications in the prototype portal application to evaluate the benefits and achievement level of security goals mentioned in [7] of Smart-RBAC model in the university environment.

1.4 Scope & Assumptions

In this section, we define the scope and assumptions of the Smart-RBAC model proposed in this thesis.

Scope:

- The location-based access control model proposed in the thesis is limited to a university context.
- **Assessing usability and testing performance parameters are out of the scope of this work.** The model proposed in the thesis is validated with the help of a prototype and evaluated based on a theoretical procedure given in [7]. Due to the lack of time and resources, the usability study and performance testing is not performed for the created prototype.

- **Functions of “Administrator” [12] of the access control model is not discussed in the thesis.** The model proposed in this thesis is a variant of role-based access control models (RBAC) [2], that has a system administrator to define the roles, permissions, content and operations of the model. The functions were not discussed as there are many documents available online with an elaborate explanation, for example, the RBAC model used for the prototype of this thesis, Liferay¹ RBAC administrator guide is available at [13].
- **“Administrator” is not categorized as a user of the organization.** There are two reasons for the aforementioned statement, the “Administrator” has all the permissions present in the model resulting in access to all operations and content irrespective of location and the “Administrator” is not confined to an organization. Therefore categorizing “Administrator” as a user would be a futile exercise.

Assumptions:

- As the users of the model are the university members like students, faculty, maintenance staff, etc. We assume that the term “user” used in the model, refers to a real human being.
- We assume that the user has opted-in and expressed interest in sharing his/her location in order to use the application implementing the Smart-RBAC model. The assumption was made as the model is dependent on the input of user’s position.
- For offering more flexibility to the users, we assume that the user need not be physically present for viewing location-based content.
- The proposed model, Smart-RBAC, does not automatically change the user’s location-specific role based on his/her position and requires a permission from the user. Therefore, we assume that the user has the capability to decide whether to activate his role corresponding to his/her current location.
- The proposed model does not support role hierarchy in the location-specific roles, therefore we consider the locations of resources as

independent entities and does not account the spatial relationships between them.

1.5 Outline of Chapters

The dissertation consists of 8 chapters: *Introduction*, *Literature Review*, *Proposed Model: Smart-RBAC*, *Smart-RBAC Prototype: University Jaume I Case Study*, *University Jaume I Smart Campus Portlet Applications*, *Evaluation and Discussion*, *Conclusions and Future Work*, and *Bibliographic References*. In addition, there are two appendices: *Appendix A: Tests* and *Appendix B: Application Code*.

The *Introduction* chapter provides a brief description of the dissertation and the potential benefits of utilizing the role of a user in a smart campus environment. Moreover, it discusses the motivating factors that lead to the development of a new approach to deliver content based on a user's role alongside the user's physical location. Furthermore, it lists the objectives of the dissertation that we aim to achieve by the end of this thesis. The scope and assumptions of this work are also specified in this chapter.

The *Literature Review* chapter provides a synopsis of the existing work regarding the topics like context-aware computing and location-based access control models. In addition, we analyze the shortcomings of the existing models when considered in a content delivery perspective. In the *Proposed Model: Smart-RBAC* chapter, a new model has been proposed to overcome the existing shortcomings by increasing flexibility through relaxing rules regarding the user's physical location. The proposed model is explained along with its components by utilizing a real world example, in detail.

The *Smart-RBAC Prototype: University Jaume I Case Study* chapter describes the procedure to develop a prototype application based on the proposed model in the

previous chapter. It defines the scope and details the architecture of the prototype application along with the software used. This prototype is derived from the proposed Smart-RBAC by extending Liferay's RBAC features. In addition, it discusses the prototype application implementation and details the process workflow of the prototype in multiple scenarios.

The *University Jaume I Smart Campus Portlet Applications* chapter lists out the different portlet applications created with the objective of exploring the benefits of the proposed model. The design, implementation and testing of the applications like *Customized Smart Campus UJI*, *Customized Liferay Built-in Applications* and *Location Analytics*, are discussed in detail.

The *Evaluation and Discussion* chapter analyzes the proposed model through its prototype and evaluates the model based on the “theoretical framework” proposed in [7]. In particular, we assess our model according to their level of achievement of security goals. This chapter further discusses the benefits, potential pitfalls and the difficulties faced during implementation of the prototype.

The *Conclusion and Future Work* chapter analyzes the extent to which the objectives, mentioned in *Introduction* chapter, are met through the implementation of the proposed model. Finally, we discuss the potential areas where the model can be refined and extended. *Appendix A* contains the details about the tests performed to evaluate the prototype and the portlet applications. *Appendix B* lists the different components of the application code and provides links to access the code in Github².

² <https://github.com/> [accessed on Jan 28th, 2015]

2 Literature Review

In this chapter, we present a selection of relevant works with regard to the topics like context-aware computing and location-based access control model.

With the increasing role of ubiquitous computing[14] in our daily lives, there is a need of “context-aware”[15] applications that utilizes the context of the user to reduce the complexity and improve usability. Context according to [16], is defined as “*any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves*”. For example, consider the case of interactive bus timetable application that utilizes the location and time as a context for showing bus timings based on the user’s position and time of access. There are many examples where position and the surroundings of the user are considered as context. For instance, in [15] user’s location, people/ objects in the near proximity and the change in the state of objects over time are considered as context.

In [16], four main categories of context are defined, such as “location, identity, time and activity” that are termed as “primary context types” that helps to describe a situation. The context information can be acquired through different types sensors, for location information the sensors are Global Positioning System (GPS) [17], Wi-Fi Positioning System(WPS) [18], etc. Defining and storing contextual information requires a context model[19] that covers an array of potential contexts. [20] compiled the data structures used in “most relevant context modeling approaches” for storage and retrieval of context details. They are “*Key-Value models, Markup scheme models, Graphical models, Object Oriented models, Logic-based models and Ontology based models*”[20].

[16] defines context-aware computing in the following way:

“A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user’s task”.

Some of the features of a context-aware application are based on the type of user’s interaction with the application[21]. The application can utilize the context and suggest the user a list of options regarding information to choose from or can automatically provide information. The most common context component among the context-aware applications is location owing to the advances in wearable/ portable technology. There are many examples of location-aware systems[19], such as tourism information systems that makes use of tourist’s position to suggest options [22], [23],[24], Location-aware information delivery with ComMotion[25], Conference Assistant[26], etc.

With the emphasis on modeling the context, there lies a risk of neglecting the user entity in context-aware computing [27]. The paper [27] presents a common example of tourist guide system and argues for considering both the user’s context and attributes of users for extracting meaningful and satisfactory information from the system. Therefore, user-adaptive context-aware systems are required which consider user’s behavior, “longer-term characteristics” like profession, gender, etc and current state (“cognitive and/or psychological”). The ComMotion[25] project mentioned earlier presents a “user-centric location model” that delivers personalized content according to the user’s previous “mobility patterns” and position.

One of the important challenges in context-aware computing is to control access to different resources in a system to handle the vast potential of contextual changes[28] and to reduce the risk of unintended access to sensitive information in the respective application due to its pervasive nature. There are different access control mechanisms available like Access Control List (ACL), Discretionary Access Control (DAC)[29], etc. These traditional access control mechanisms are not suitable for pervasive applications as they do not factor in the user context[30]. Role-based Access Control (RBAC) model [2] is a type of access control that utilized the concept of “roles” to manage security permissions and access rights of the users in a system. The main purpose of “roles” are to act as a middle layer between the users and the permissions to

access a resource. Earlier, access control model used to group the users and assign the permissions directly. In RBAC, permissions for accessing the resources are not assigned directly to users, instead “roles” are used to assign permissions and in turn these “roles” are assigned to the users. The main benefit of using the concept of roles is to avoid the unnecessary work of assigning the same permissions to different users or user groups, moreover the concept is simple to implement. RBAC models can be extended to introduce context information, therefore rendering it suitable to model user, context, and access control. The examples of different RBAC models that are extended to include user’s position as context are mentioned below.

In the paper [31], the authors tried to improvise the traditional Role-Based Access Control (RBAC) [2] to enhance the security features in future smart homes, etc. They proposed a model, Generalized RBAC that overcomes the traditional RBAC’s existing limitation of restricting the “policy designer” to a user-centered perspective. The model assigns roles to “all entities”, including the resources and their respective “environmental states”. It has two extra roles apart from the traditional RBAC’s “subject roles”, they are: “environment roles” and “subject roles”. This concept of evaluating access based on role makes this model more useful as it can support temporal-based scenarios as well as state-based scenarios.

The authors of [31], presented another model “Environment RBAC” [32], focusing more in detail about the “environment roles” component of “Generalized RBAC”. It mainly deals with “problem of securing context-aware applications” in a location-aware environment. It describes the collection of the attributes that determine the “environmental roles” and a mechanism to authenticate the information collected. A typical environmental state depicts a state of the system, for example, restricting access to a resource on particular dates, etc. It is easier to determine the separation of duty constraints [33] for the environment roles as they are dependent on the system state. However, as environment roles are dynamic in nature, using sessions to activate the role might not work. Thus making it difficult to “enforce the principle of least privilege”.

In the paper [34], a new model Spatial RBAC has been proposed, that makes use of the geographic information to define security constraints for accessing resources in the system. It proposes a method of varying the permissions of a role assigned to a user according their respective location. This model reduces the burden of creating separate roles for each location inside the organizational domain. Therefore, in an organization where there are many location-specific constraints, assigning a single role to the user and changing the permissions according to the user's location would offer more flexibility.

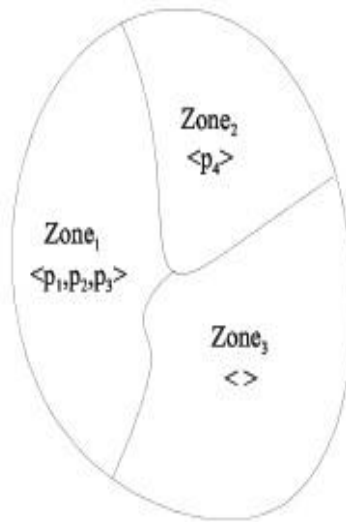


Figure 2: Logical location domains with available permissions [34]

Figure 2, depicts an example where there are three zones/locations with different permissions associated with them, Zone₁ has three permissions p_1 , p_2 , p_3 . When user enters Zone₃ from Zone₁ the permission of p_4 will be activated.

The paper [34] describes the components of the Spatial RBAC model like “Core Spatial RBAC”, “Hierarchical Spatial RBAC” and “Constrained Spatial RBAC”. The model defines “Spatial Static Separation of duty (SSSD)” relations to check for conditions to assign users to certain roles when they are in a particular location. Therefore, the model does not allow the user to have two roles of conflicting nature at a particular location.

Similarly, “Spatial Dynamic Separation of duty (SDSD)” relations check for conditions to assign permissions to a role for a user in a session (See Figure 3).

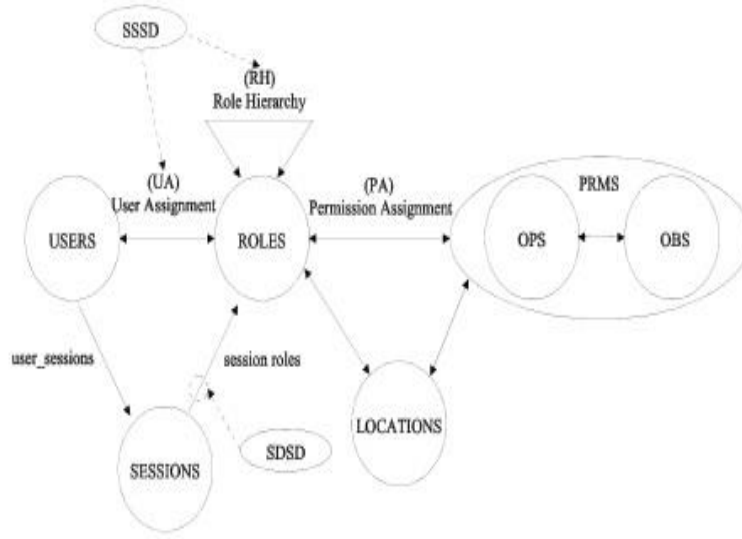


Figure 3: Spatial Separation of Duty relations [34]

The above-mentioned SRBAC model was applied in a healthcare information systems, that allows remote access through wireless technologies [35]. The model SRBAC helps in controlling the access to sensitive information present in the healthcare information system based on the location of the user, in this case, the healthcare personnel.

Similar to the SRBAC, [36] proposed a new model, GEO-RBAC for integrating the location-based constraints to the traditional RBAC. This model differs from the earlier mentioned model by its capability of handling requirements like “multigranularity of position” and “relationships in space”. Concept of Spatial role is introduced where it “represents a geographically bounded organization function”. The model utilizes an Open Geospatial Consortium (OGC) [37] compliant spatial model for geometric representation of the spatial objects. GEO-RBAC uses the concept of role-schema and role instance that represents a group of “spatial roles” and constraints regarding their activation and the role realizing the constraints respectively.

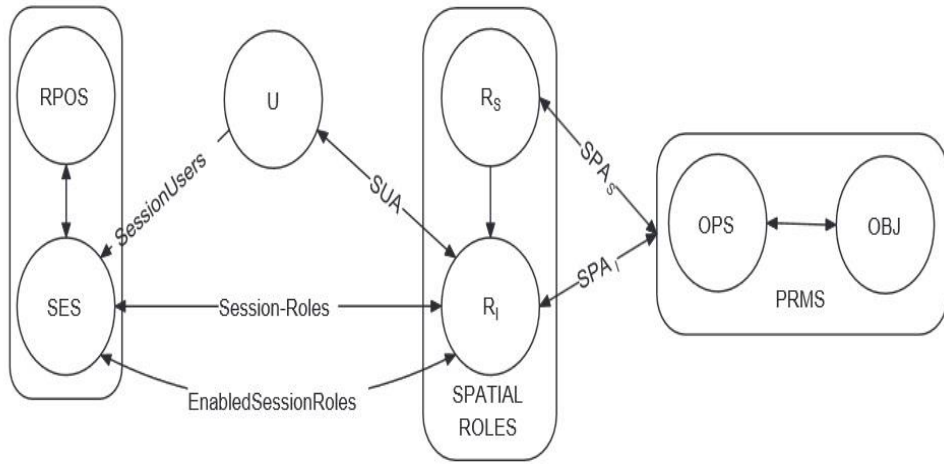


Figure 4: Core GEO-RBAC [36]

In the figure 4, R_S and R_I represent role schema and role instances respectively. Only the permissions PRMS can be “associated with role instance and role schema”. This model utilizes the user’s location information for enabling the roles in a session. This model, however, does not deal with conflicting constraints like role extents and user positions. There are extensions of GEO-RBAC like GEO-RBAC_C [38] that enables the access control model to monitor the movement of the user.

The paper [39] describes a location-based control model extending RBAC like the previously mentioned models. A formal model, using the Z specification language, is proposed explaining the relation between different entities of RBAC and the location.

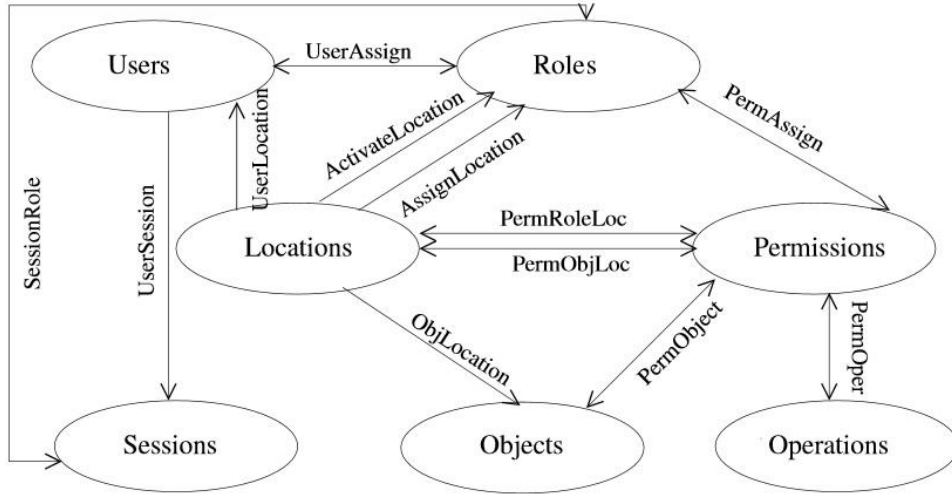


Figure 5: Relationship between RBAC components and Location [39]

This model supports additional operations like “Addlocation” and “DeleteLocation”, on the condition that the location to be added should be present in the existing set and the location that should be deleted should be associated with any role or permission. However, this model does not consider the role hierarchy and separation of duty (See figure 5).

Other related work includes, [40] used semantic technologies to build an access control system, [41] integrated social interactions of the user along with location information in an RBAC. The paper [7] undertook a review of evaluating the effectiveness of location-based access control models (LBAC) in different usage scenarios and listed the potential research themes for the future. We use the evaluation framework presented in this paper [7] to partially evaluate our model Smart-RBAC.

Need for a new model:

In the above section, we notice that all the existing location-based access control models are primarily focused on the security aspect by enforcing stringent rules. However, our objective of user-specific location-based content delivery requires a model that focuses on multiple ways to represent position and profile of the user. However, the existing

models has some shortcomings for achieving the aforementioned objective, some of them are discussed below.

Two important problems [7] were identified with regard to usage of existing models in delivering location-specific content. Firstly, existing models enforce the rule that the user needs to be physically present in a location to access its content. However, this restriction would require the user to move for simple information. For example, if a user wants to check the schedule of an event that takes place in a building away from the user's current physical location, then the user has to physically move to the building to access the content. Secondly, existing models automatically assigns permission to roles or roles to the user with respect to user's physical location. In the cases where the user moves around the physical space, the role change or permission change would be occurring throughout the journey. For example, if a user passes by five buildings in a university campus during a transit, then the roles change according to the nearest building of user's location at a particular moment. This scenario results in cluttering of the user device with the information of the five buildings in a short span of time through the transit, thereby reducing the performance as well as the readability as the information keeps changing.

Therefore enforcing restrictions based on user's physical location in existing models needs to be modified to improve usability of the access control model to deliver location-specific content. Our Model Smart-RBAC addresses these problems mentioned above and designed primarily with focus on delivering content specific to user's location. Smart-RBAC solves the above problems by providing the feature of manually modifying user's location-specific role and asking for permission from the user to change his/her role. Basically, we follow the principle of existing models of assigning location-specific roles based on user's physical location. However, the location-specific roles and user's physical location are not tightly coupled like in other models, therefore providing flexibility and enhancing the usability of applications where content delivery is the primary objective.

3 Proposed Model: Smart-RBAC

This chapter provides details of the proposed model and explains it by providing a real world example.

3.1 Introduction:

The proposed model takes inspiration from the existing approaches of including location component in the traditional RBAC. However, it extends an existing RBAC, instead of creating an entirely new access control system as proposed in other approaches. It was designed to handle the typical requirements of a university campus, which can be considered as an organization[11] with comparatively lesser number of entities than a traditional organization. We have customized the model presented in [39] to model the relationships between different entities (See figure 6).

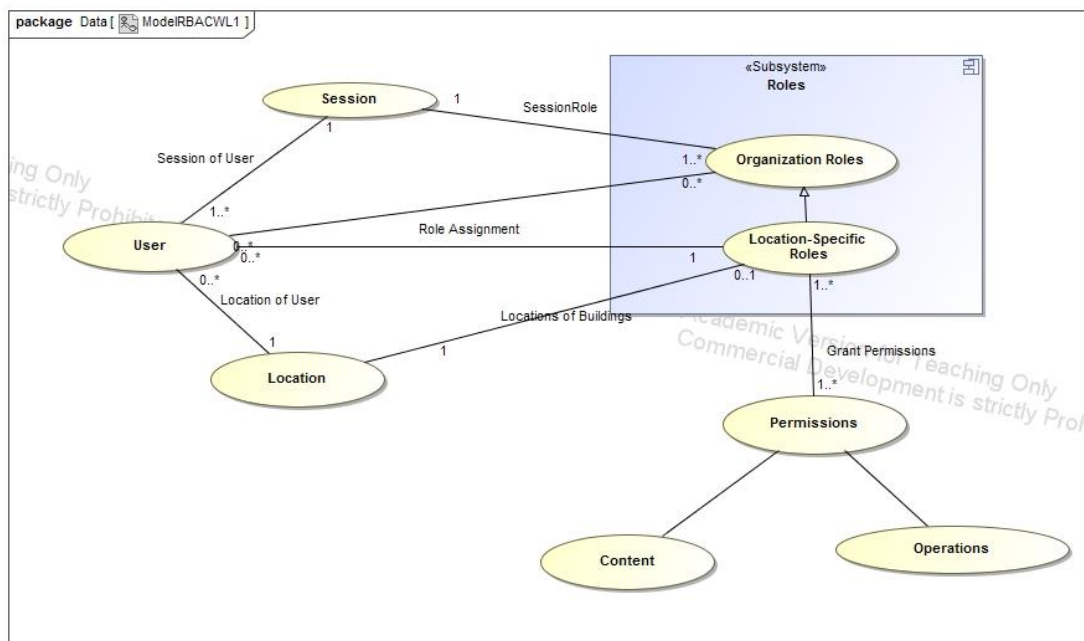


Figure 6: Relationship between different entities in Smart-RBAC

3.2 Components of Smart-RBAC Model

As mentioned earlier, we work on the assumption that the user shares his/her location. The components in the Smart-RBAC model (see figure 6) are explained as follows:

User:

The User entity has custom attributes like location, mentioned in terms of the building name, and the role s/he performs in the organization. We are based on the principle that the user cannot access the server from two different locations simultaneously [39]. The User entity has a relationship with session, roles and location. Briefly summarizing the multiplicity constraint of their relationships, a user can have one or more roles and work in a single session. The relation with location needs special attention as both the geometric location and the representative location like building name are used. Geometric location will be presented by the user to the system and it converts it into a representative location to store in the system.

Roles:

The roles entity is extended from the base RBAC model. We basically work with two kinds of roles: Organization roles and location-specific Roles. Organization roles correspond to the user's status in an organization like an employee, a student, etc. We permit hierarchy in organization roles, where roles permission can be inherited to the successor roles. We have related the location-specific roles to the representative location of the user like the building name, etc. It should be noted that roles have a relationship with user, permissions and locations. As location-specific role corresponds to a location, therefore there will be a maximum of one role in a given location in an organizational domain. However, a user can be assigned more than one Organizational role.

Location:

As mentioned earlier, a location in an organizational domain can be represented by a geometrical point or an object it's contained in. Our model uses the necessary geometric features to represent the least level of granularity of location in an organizational domain. For example, in a smart campus environment we can choose polygon features to represent the buildings or the rooms to which the location-based roles correspond. For identifying the user location, we can access his device location to obtain the feature geometry point or his choice of location as the name of the building. A location can have multiple users at a given location, however, they are restricted by the model with only one role corresponding to the location. Effectively, we can achieve the objective of assigning the role only when the user is at a particular location. The model then requests permission from the user to activate the location-specific role change. A web service is used to evaluate the relationship between the geometries of the location of the user and the location of the role. However, the model allows manual input of location to assign location-specific role to avoid users to move physically in geographic space.

Session:

Sessions are handled by the base RBAC's server, whenever the user logs into the system it creates a new session. Sessions are not handled by the model, however, necessary steps are followed to ensure that the user will always have a location component while initiating the session. The user's location will be reset to his chosen location at the time of creation of the user account.

Permissions:

Permissions are associated with the roles of the model that determines whether the user can access the object in a certain mode [2]. We do not alter the permissions according to the location of the user. Therefore, the user's access to a particular content or operation will be based on the role assigned to him/her.

Content and Operations:

We can assign permissions for roles to access the content and the operations. The content and operations are specific to the domain of the application. For example, the created polls, wiki articles, layers of the maps, etc. are the content of the prototype application.

3.3 Example of the Model:

Let's consider an office environment with two rooms, Room₁ and Room₂, hosting two different types of employees Engineers and Cleaning Staff. Let's consider that there are four users, U₁, U₂ and U₃, U₄, each pair corresponding to Engineers and cleaning Staff roles in the office respectively. Now applying the Smart-RBAC model in this scenario, we get the following components:

Users: U₁, U₂, U₃ and U₄

Location:

Locations of users and the rooms. A geo-processing web service is used to find the relationship between the location of the user and the rooms. The result will be that a user is a resident of Room₁ or Room₂.

Roles: There will be two types of roles:

- a. Organizational roles: Engineer and Cleaning Staff with respective permissions. The model allows the user to have both of the organizational roles, however the system administrator would assign the role-based on the user's requirement.
- b. Location-specific roles: These correspond to the location component, thus there will be two location-specific roles: Room₁ and Room₂. A user cannot be assigned with both the location-specific roles.

Permissions:

Consider that Permissions P₁, P₂ are assigned to organization roles Engineer and cleaning staff respectively. And, P₃ and P₄ are assigned to the location-specific roles respectively.

Let's assume that at the beginning of session S₁, users U₁, U₂ are assigned to Engineer and Room₁ roles and users U₃, U₄ are assigned to Cleaning Staff and Room₂ roles. Assuming that their initial locations correspond to their location-specific roles, we would now analyze the impact of location change, movement of users between the rooms, of each user. For example, if U₁ moves from Room₁ to Room₂ and s/he agrees

for the role change then, his/her location-specific roles would change to Room₂ and the corresponding permission of role Room₂ are applied to the U₁. (See figure 7 & 8)

Initial Condition:

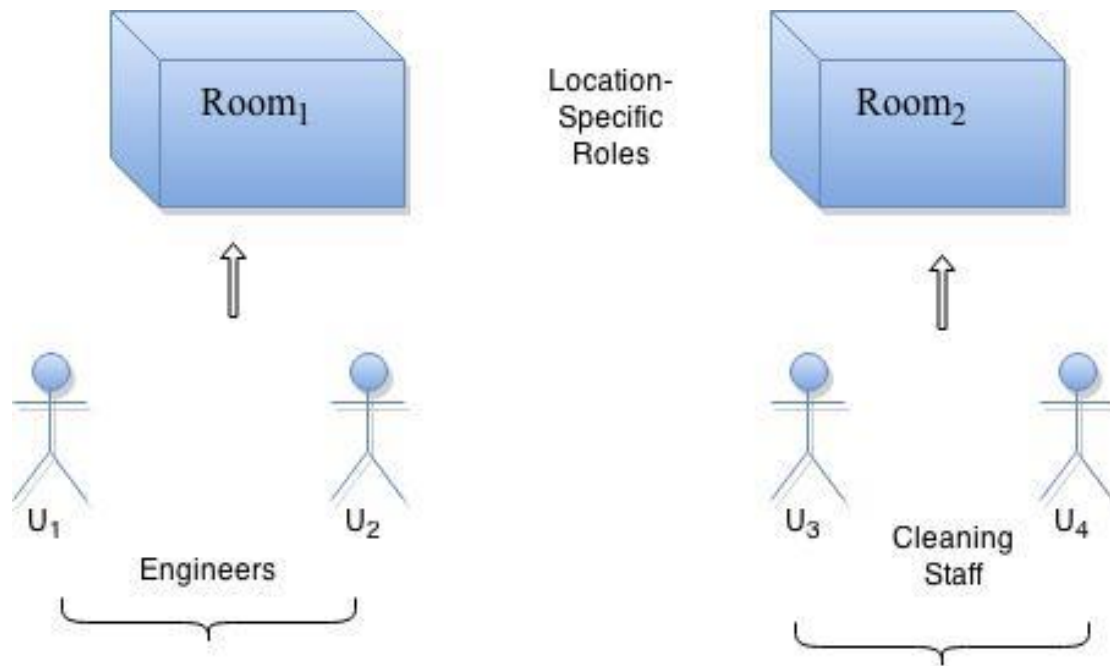


Figure 7: Example of Smart-RBAC precondition

After U₁ moves to Room₂:

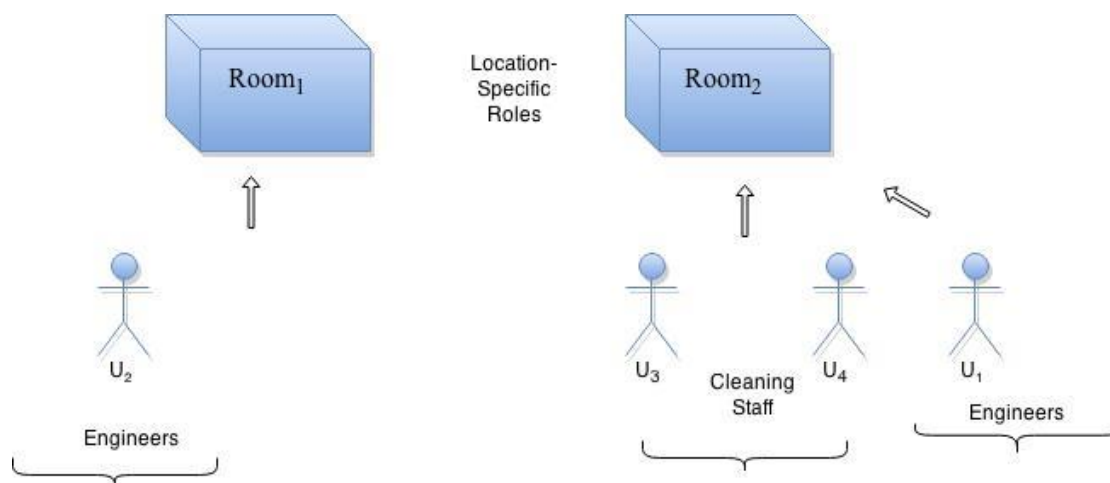


Figure 8: Example Smart-RBAC after user movement.

4 Smart-RBAC Prototype: University Jaume I Case Study

This chapter details about the prototype application developed to validate the Smart-RBAC model in a smart campus environment.

4.1 Data

We have created this prototype for the University Jaume I campus [9], Castellon, Spain. The target users for this prototype application are the different users in the campus like the academic users, maintenance staff and visitors of the campus.

The application consumes Smart UJI [42] services (See Appendix B) such as:

- a. Map service to retrieve the building features, different layers like facilities, energy consumption, parking, etc. in the university campus
- b. Geometry service to establish the relationship between the user's location and the polygon features of the buildings.

4.2 Scope

We have limited the scope of this application by restricting the range of values for each component. With respect to location component, we restrict the application to just 6 buildings, with IDs "UB", "JA", "TD", "CD", "DB" and "GG" [8]. The buildings are chosen with the purview of the movement patterns noticed on personal observation. With respect to the roles: As the site roles relate to the locations, therefore they are restricted to these buildings as well. The Organization roles are limited to three broad categories, namely academic, maintenance and visitor.

4.3 Prototype Design:

We developed a portlet-based[43] web application to serve different types of users in a university environment relevantly and to deliver designated content according to the user's role in the organization and the user's location in the campus. The application also customizes the features provided by the Liferay³ to correspond to the user's role and location. A subset of the existing Smart UJI Campus [8] is modeled in the application to demonstrate the use of organization roles for restricting the access to different services offered by the Smart Campus UJI application. The web application requires permission from the user to change the role of the user in a session, so as to deliver location-based content and orient behavior of applications.

Prototype Architecture

Portlet based web applications are best suited when there are disparate sources of web services serving raw data, as, in this case where we consume the services of smart campus that serve data in JSON⁴ format. Portlet based web applications are used to model the presentation layer in a service oriented architecture. In this application, we used Liferay³ Portal Server as the container to host the portlets [43] created with the JSR 286 Specification [44]. This portal server is in turn hosted on a web application server [45], Tomcat⁵ server (See figure 9). The portal server stores all the data in the back-end database MySQL⁶. The components versions of the application is as follows:

Liferay³ Portal Server Version 6.2 [46]

Tomcat⁵ Application Server Version 7.0.42 [47]

MySQL⁶ Database Version 5.5.39-winx64 [48]

The portal application consumes RESTful web services [49] hosted by Smart Campus UJI [8] that in turn are hosted in ArcGIS Server⁷ (Version 10.11). We had created a new feature service for the sake of this application to capture user location data (See

³ www.liferay.com [accessed Jan 28th, 2015]

⁴ <http://json.org/> [Last Accessed on Jan 28th, 2015]

⁵ <http://tomcat.apache.org/> [Last Accessed on Jan 28th, 2015]

⁶ <http://www.mysql.com/> [Last Accessed on Jan 28th, 2015]

⁷ <http://www.esri.com/software/arcgis/arcgisserver> [Last Accessed on Jan 28th, 2015]

Appendix B). The Liferay's RBAC [3] , is used to derive our proposed model and the figure 10 depicts the typical roles and their hierarchy present.

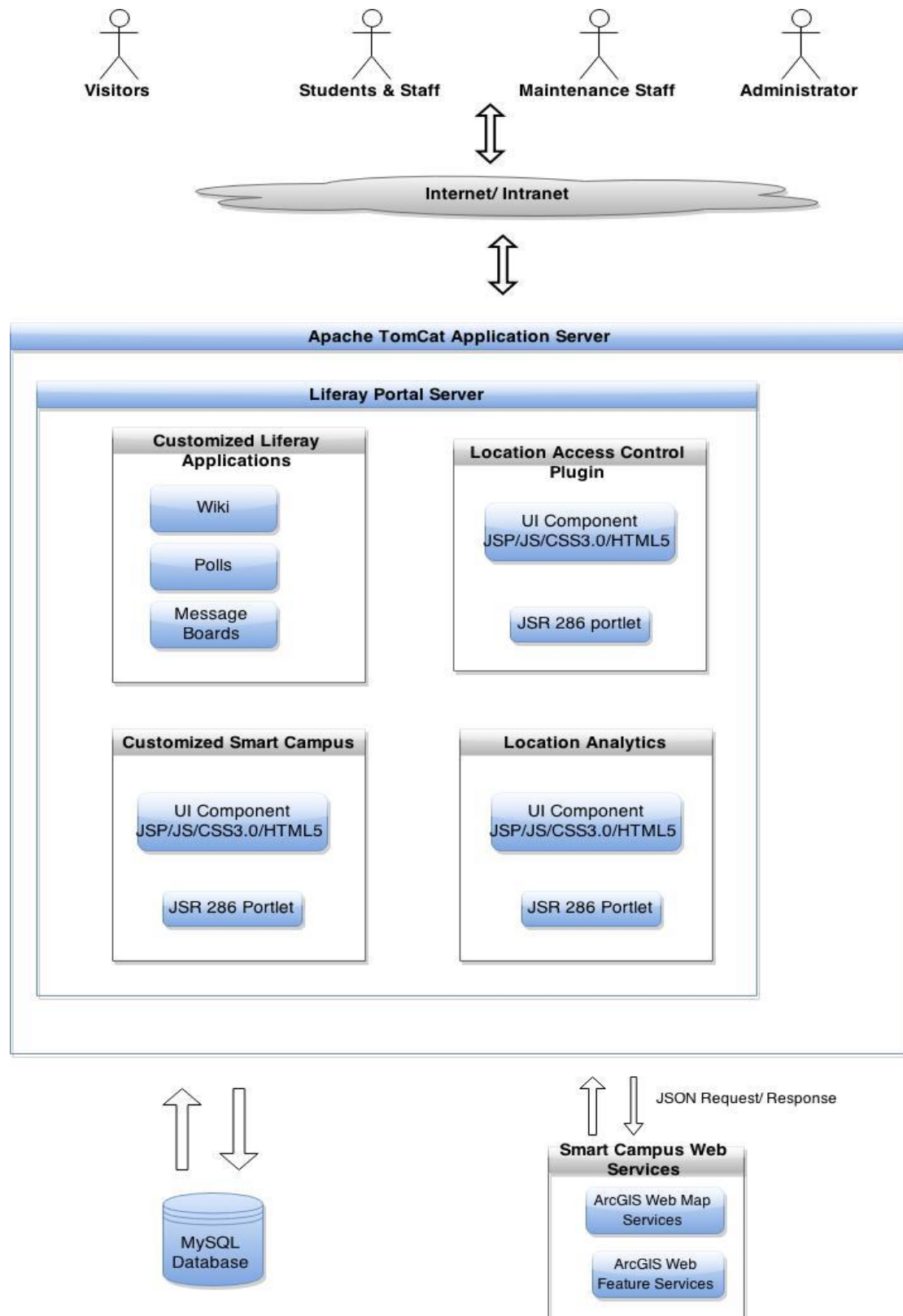


Figure 9: Prototype Portal Application Architecture Diagram

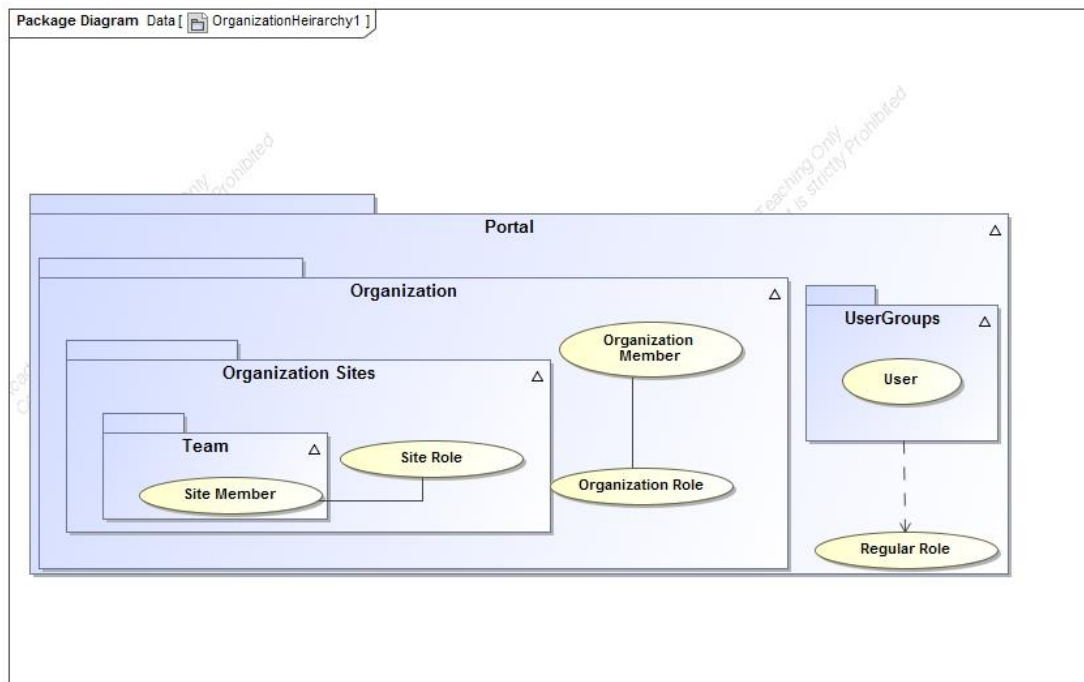


Figure 10: Role Hierarchy in Liferay RBAC

4.4 Derived Smart-RBAC model by extending Liferay RBAC

We mapped the different entities in a university environment to the Smart-RBAC model. We had created an Organization named “UJI” for the application. The following components are resulted from the mapping process:

Users:

We had broadly classified the users into three main categories in the University Jaume I (UJI) campus [9]. They are:

UJI Academic: This category is associated with the users involved in academic activities in UJI. This category includes students, professors, and research assistants.

UJIMaintenance: This category is associated with the users involved in maintenance activities in UJI. Some of the examples are facilities employees, library employees, security personnel, etc.

UJIVisitor: This category is regarding the visitors of the UJI campus. Users without UJI credentials are defined as UJIVisitor. The category includes prospective students, visitors etc.

Figure 11 lists out the different applications accessible by different users categories in the UJI university smart campus.

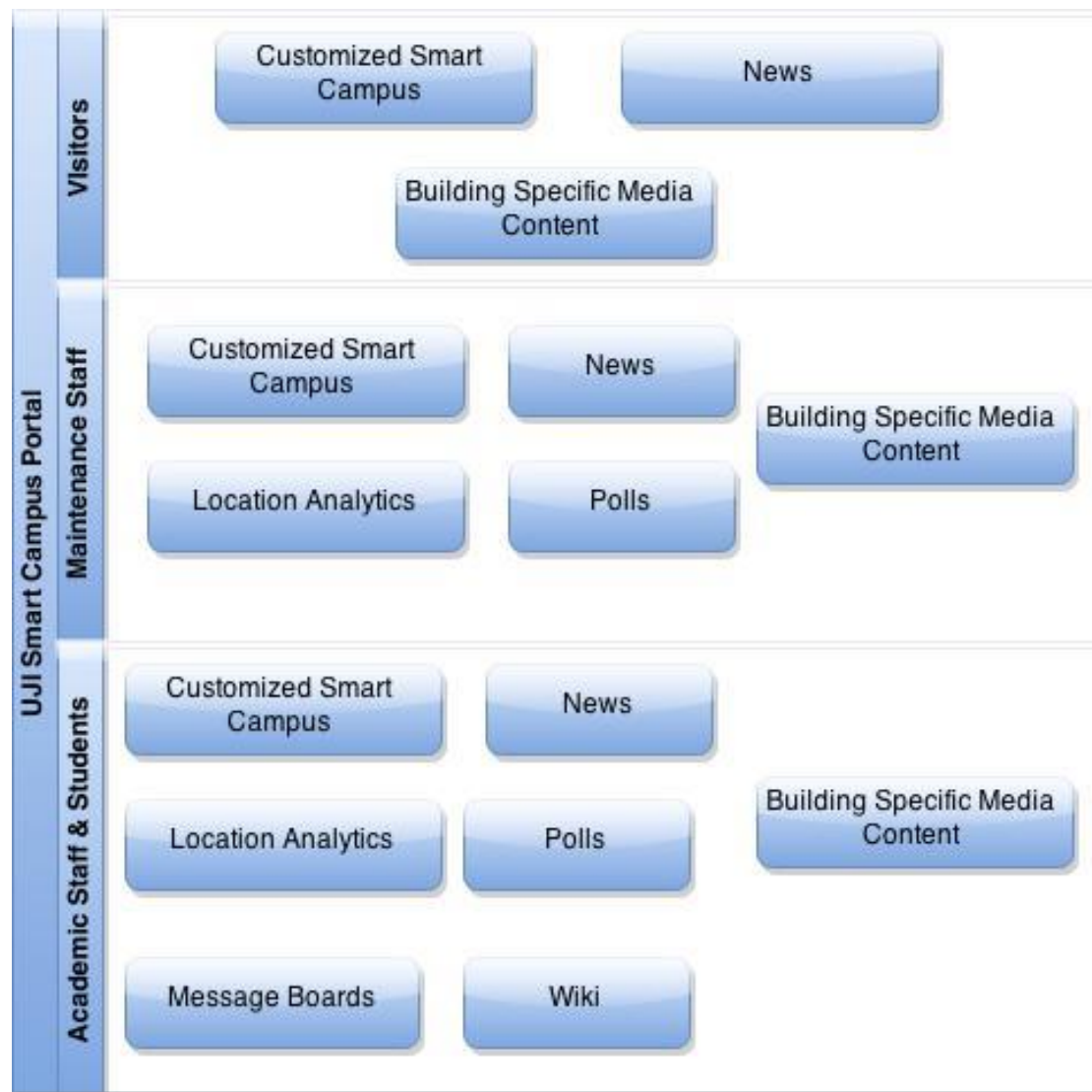


Figure 11: Applications accessible for different user categories.

Location:

We define our location domain as the campus extent. And the locations as the geographic extent of the buildings in the campus. As mentioned earlier, we restrict the locations to 6 buildings in the campus. The locations of the roles are:

“TD”, “CD”, “UB”, “DB”, “JA”, “GG” [8].

The geographic location of the user is shared by the user to identify the relationship to the above 6 buildings for the user. We use a geometry server hosted by Smart Campus UJI to perform this analysis through an **AJAX**⁸ call. The service returns the building name of the user if the user is inside the building or in the **vicinity of around 10 meters of the building**.

If the user is not inside the location domain of the campus, i.e. if the user’s location is detected to be outside the campus, then a message will be displayed on the Graphical User Interface (GUI) informing the user of the same. In such a case, the system will use the user’s previous session data and continue his role from that session. All the content and applications behavior will be in synchronization with the last known role of the user. The same scenario is applied if the user is in the campus and outside the 10 meter tolerance limit of any building.

Moreover, we provide a means to locate the user’s current location manually by clicking or touching (in case of smartphones) on his desired building on a map. This map is configured to capture the location information of the user’s click or touch and query it against the Map service of Smart Campus UJI [8]. The query returns the building name of the polygon with respect to user’s input to the system. If the building name is in scope, then this building name would automatically be transferred to the portlet plugin in the backend to change the user site role to the new location. This manual option is created according to Smart-RBAC model and used as a means to simulate data from the system as it would be physically tiring job to move to different locations on the map to capture the data. (see figure 12 for the decision tree)

⁸ <http://www.w3schools.com/ajax/> [Last Accessed on Jan 28th, 2015]

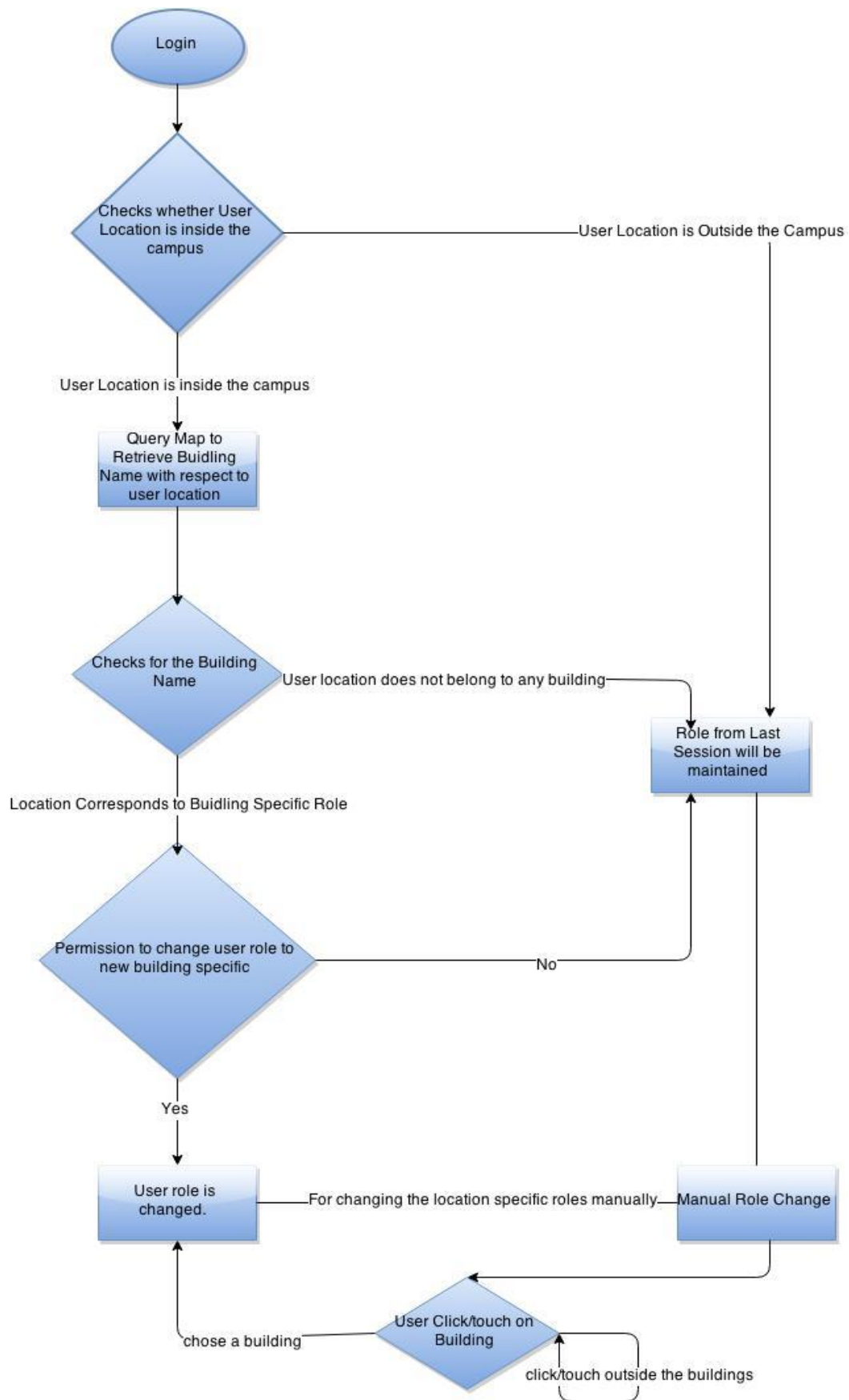


Figure 12: Decision Tree for assigning location-specific role

Roles:

According to the Smart-RBAC model, the users organization relationship and location component are mapped to the organization roles and the location-specific roles in the model. In the derived model, which is based on Liferay's RBAC [3], the location-specific roles are assigned to site roles(see figure 13). The organization roles are:

UJIAcademic: This role is mapped to the category of users “UJIAcademic”, subsequently all the users who are involved in academic activities in UJI are assigned to this role. In our prototype, this organization roles has more permissions assigned when compared to the other two organizational roles.

UJIMaintenance: This role is mapped to the category of users “UJIMaintenance”. All the users related to the maintenance activities in UJI are assigned to this role.

UJIVisitor: The role is mapped to users who are visiting the campus or the prospective students. This role has minimum permissions assigned to it when compared to the other two organizational roles.

Liferay RBAC allows hierarchy in the organization, thus if we want to extend these organizational roles, we need to create sub-organization for each organizational role or the desired organization role.

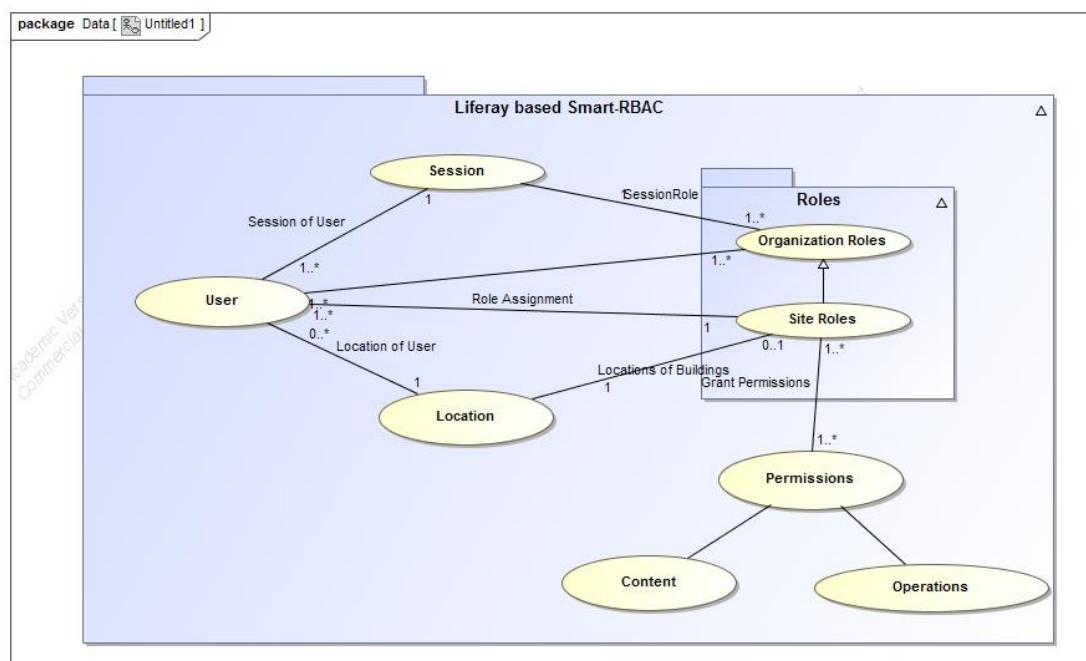


Figure 13: Derived Liferay based Smart-RBAC model

The Site roles [12] that correspond to location are “TD”, “CD”, “UB”, “DB”, “JA”, and “GG”. The Application enforces the constraint of the Smart-RBAC model that no user can have more than one location-specific role, in this case of derived model, its site role.

4.5 Prototype Implementation

4.5.1 Technical Overview

We developed 7 portlet plugins for implementing the Smart-RBAC model and for creating applications and customizing existing feature portlets provided by Liferay that benefit from Smart-RBAC model, in an Integrated Development Environment (IDE). The Liferay³ portal server is installed along with the Tomcat⁵ Application Server and connected to the MySQL⁶ database. Liferay portal server has an inbuilt content management system to manage content and an RBAC to manage access control permissions. For request maps and geographic features from Smart Campus UJI [8] services, we used AJAX⁸ and ArcGIS API for JavaScript [50]. We used JSP[51] and Liferay Alloy UI framework [52] along with HTML 5[53], XML⁹, JavaScript¹⁰ and CSS 3.0¹¹ to create the views for the application portlet plugins. To elaborate the details regarding the structure and architecture, we use an example of “IdentifyRolebyLocation-portlet” plugin.

4.5.2 Structure of the Portlet Plugin

This portlet plugin is used to assign a location-specific role to the user if the user’s location is inside or around 10 meters of the location-specific role’s geographic extent. The business logic is written in the “IdentifyRoleByLocationPortlet.Java” portlet class and the UI component is written in the files “view.jsp”, “main.js” and “main.css” (see figure 14). The plugin’s portlet definition file is “liferay-portlet.xml”. This file defines the portlet class, UI component files and security preferences to the server during deployment. The security preferences tag in the “liferay-portlet.xml” (see figure 15) defines the permissions to the portlet, for example in the case of

⁹ <http://www.w3.org/XML/> [Last Accessed on Jan 28th, 2015]

¹⁰ <http://www.w3schools.com/js/> [Last Accessed on Jan 28th, 2015]

¹¹ <http://www.w3.org/Style/CSS/Overview.en.html> [Last Accessed on Jan 28th, 2015]

“IdentifyRolebyLocation-portlet”, the portlet XML file defines permissions for only the “Administrator”. The application code links are specified in the Appendix B.

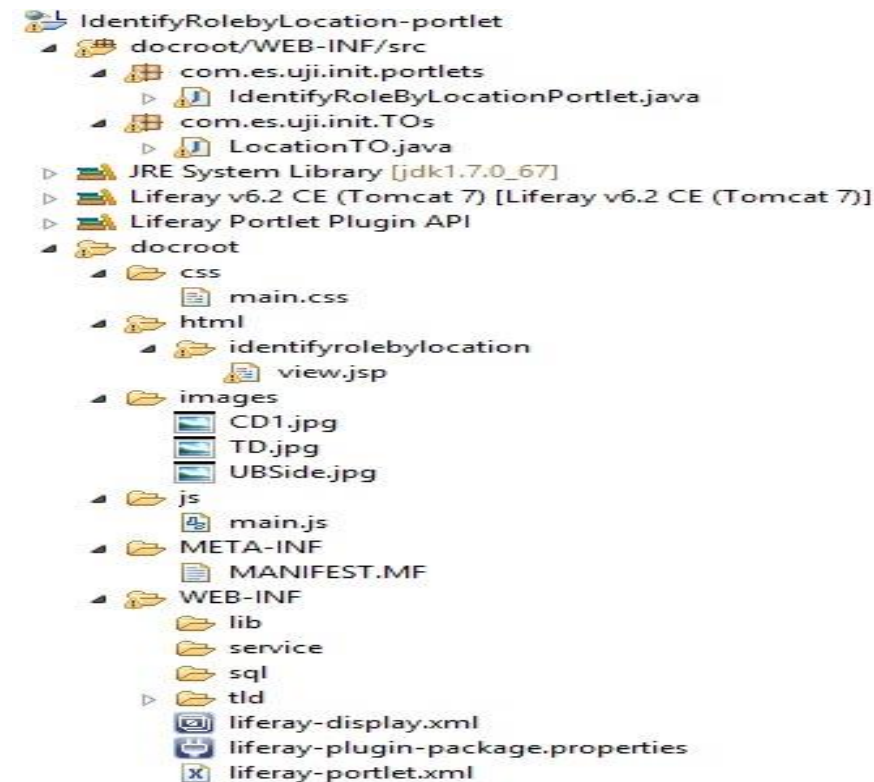


Figure 14: Example structure of Portlet Plugin

```
<?xml version="1.0"?>
<!DOCTYPE liferay-portlet-app PUBLIC "-//Liferay//DTD Portlet Application
6.2.0//EN" "http://www.liferay.com/dtd/liferay-portlet-app_6_2_0.dtd">
<liferay-portlet-app>
  <portlet>
    <portlet-name>identify-role-by-location</portlet-name>
    <icon>/icon.png</icon>
    <header-portlet-css>/css/main.css</header-portlet-css>
    <footer-portlet-javascript>
      /js/main.js
    </footer-portlet-javascript>
    <css-class-wrapper>
      identify-role-by-location-portlet
    </css-class-wrapper>
  </portlet>
  <role-mapper>
    <role-name>administrator</role-name>
    <role-link>Administrator</role-link>
  </role-mapper>
</liferay-portlet-app>
```

Figure 15: A typical liferay-portlet.xml file

4.6 Process Flow Diagram

The process flow diagram represents the sequence of activities performed by the user and the system during a session (see figure 16).

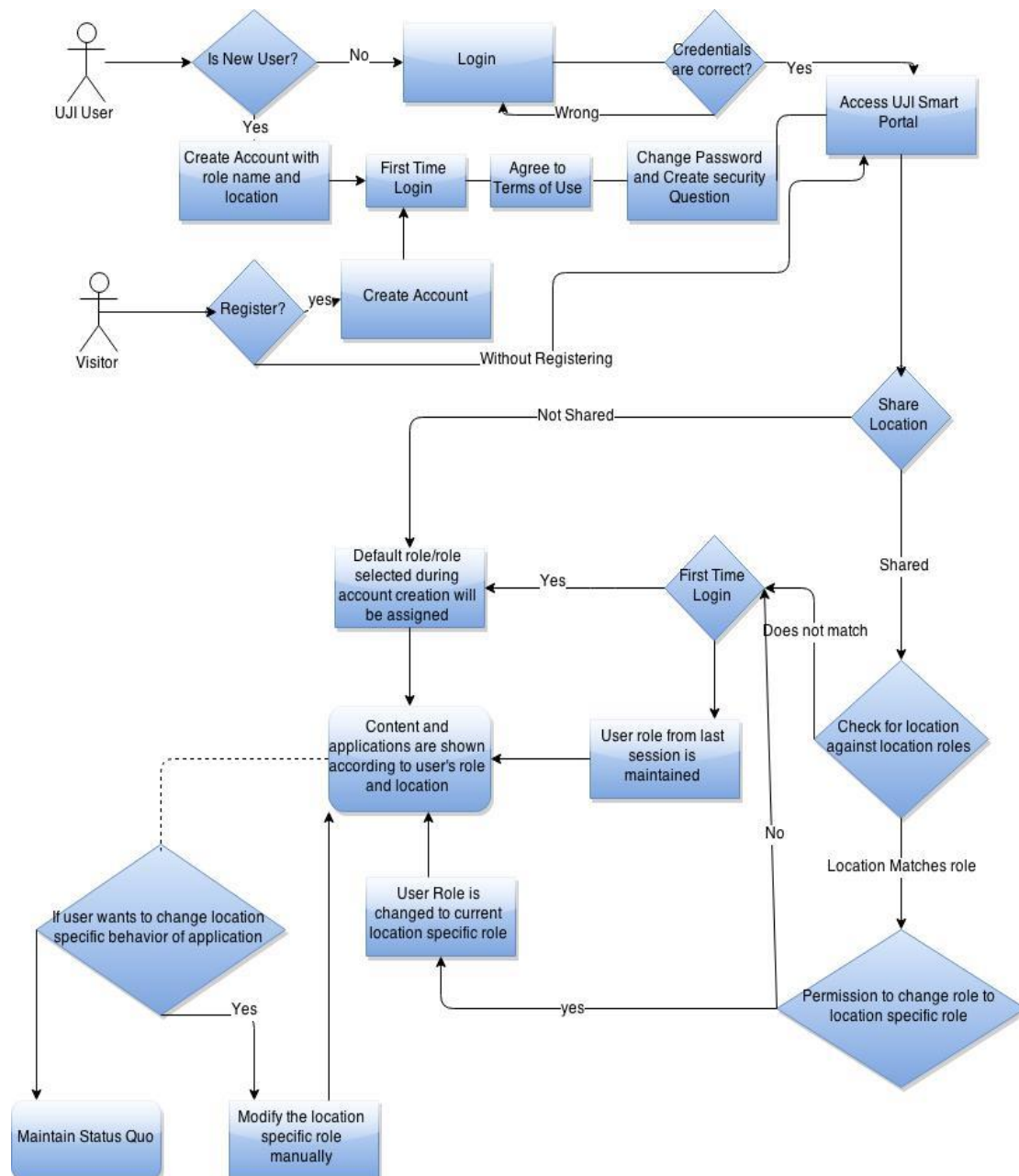


Figure 16: Process Flow Diagram of the Smart-RBAC UJI prototype

We can divide the process of logging (see figure 17) to the portal application into different scenarios for different types of users:

1. UJI user(Academic and Maintenance) who is not registered in the portal application
2. UJI user(Academic and Maintenance) who is a member of the portal application
3. Visitor who wishes to register and access the portal application
4. Visitor who wishes to access the portal application directly.

Scenario 1: UJI user (Academic and Maintenance) who is not registered in the portal application

The first page or the landing page of the application displays the Login option wherein the user needs to enter his/her credentials. If the user is new, s/he should click on “Create Account” link that directs to a registration form where s/he needs to provide details like name, email, etc., and importantly s/he can specify whether s/he belongs to the UJI Academic role in the university or the UJI Maintenance role. And he can also specify which building/location he prefers as his default location, so that when the user logs in he will be assigned to that location role with an option to change to his current location role. The default values of organization role and site/location role are “UJI Academic” and “CD” respectively. Therefore, if the user does not specify his preferences at the time of registration, s/he needs to contact the administrator for changing the organization role, whereas the control to change the site role is always with the user.

Before the creation of the user account in the server, we use “OnBeforeCreate” method in a listener class to assign the role values chosen during the time of registration to organization role.

When the user creates an account, the server generates a password and displays on the screen. The user uses that password only for the first login, agrees to the terms of use and will be forced to change the password and set a security question once s/he logs in.

Before the landing page, the system will assign the location role of the user to the one chosen at the time of registration.

Scenario 2: UJI user (Academic and Maintenance) who is a member of the portal application

The UJI user is required to enter his/her credentials in the login page of the portal application. The portal server authenticates the user's credentials and allows access to the application.

Scenario 3: Visitor who wishes to register and access the portal application

If the visitor wishes to register to the portal application, then s/he should click on the link "Visitor? Do you wish to register? Click Here", that will be directed to a registration form where s/he needs to provide details like name, email, etc. The visitor user will be assigned "UJIVisitor" and "CD" as values of organization role and site/location role respectively. When the visitor creates an account, the server generates a password and displays on the screen. The visitor uses that password only for the first login agrees to the terms of use and will be forced to change the password and set a security question once s/he logs in. The visitor can use his/her password to login to the application in the future.

Scenario 4: Visitor who wishes to access the portal application directly


Visitors who just want to access the application directly will click on the link in the login page with the name "To Access without Registering". The visitor will directly access the application with the organizational role as "UJIVisitor". We use an autologin process to achieve this functionality.

LandingPage

LandingPage

Sign In

Universitat Jaume I Smart Campus Portal



UJI Portal Sign In

Screen Name

This field is required.

Password

☐ Remember Me

Sign In

For Visitors of UJI

To Access Without Registering

Visitor? Do You Want to Register? Click Here

For Univerity Jaume I Users

Create Account

Forgot Password

Powered By Liferay

Figure 17: UJI Smart Campus Portal Login Page

Post-Login process:

Smart Campus Portal Home page will be shown once the user logs in, which requests the user to share his/her location. Though our assumption states that the user always shares his location, the model also handles scenarios where the users are not willing to share the location by displaying content and application related to the location/building chosen during the process of account creation. If the user shares his/her location, then we would first check whether the location lies in the extent of the campus. If the user's location is outside the campus, then we would check whether the account has previous sessions recorded. If there are any previous sessions recorded for the user, then the last known location would be used to display the content and define the behavior of the

applications. In case of first-time login users, where there are no sessions recorded in the past, we will use the location information provided by the user at the time of account creation to display the content (see figure 18).

In the case, where the user's location lies inside the campus, we will create a query using ArcGIS API for JavaScript[50] against the map service of Smart Campus UJI [8], specifically to the Buildings map service. The query returns the "BUILDINGID" if the user's location is in/around 10 meters of the UJI campus buildings. Kindly note that our scope limits us to just 6 buildings in the campus. If the retrieved "BUILDINGID" matches to these 6 chosen buildings, then the user will be eligible to the new location-specific role. The user will be assigned to this new role, after his acknowledgment on the home page. If the user does not wish to change his role, or if the query does not return a valid "BUILDINGID", then we will check for the condition of previous sessions and assign the role.

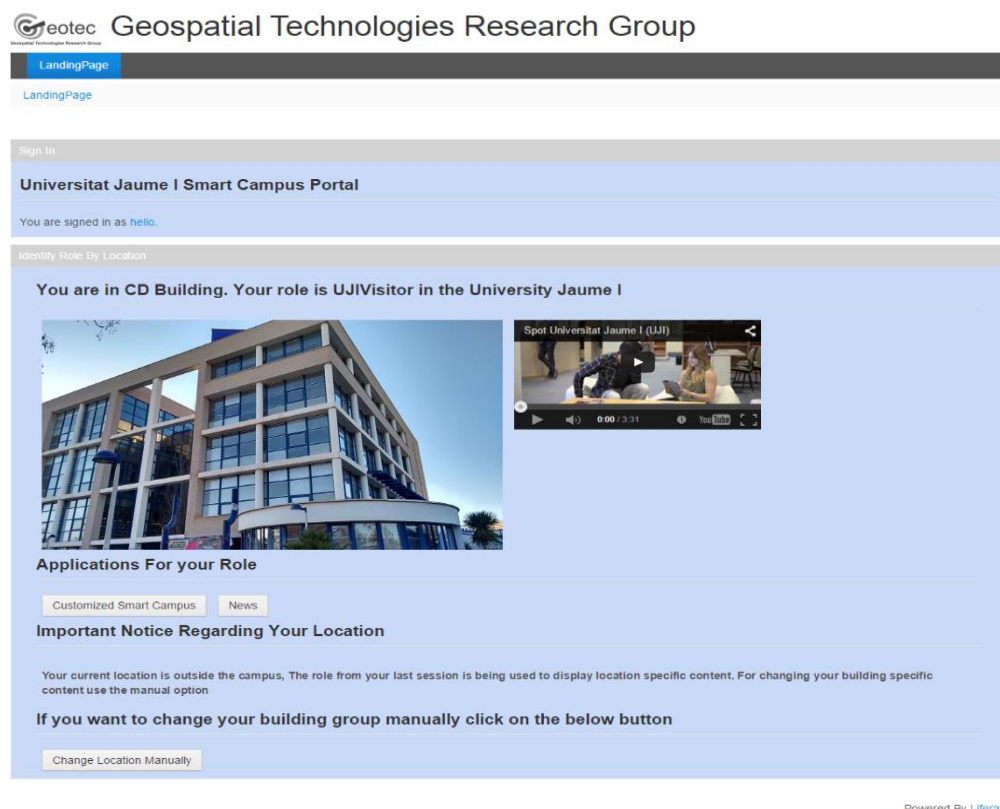


Figure 18: UJI Smart Campus Portal Landing Page for Visitor

4.7 Manual Option to change Location-specific roles

Considering the fact that the location-specific role change is dependent on the movement of the user, we had implemented an alternate method of manually assigning location-specific roles. This option (see figure 19) is created to avoid the physical movement of the user everytime s/he needs location-specific information as specified in the Smart-RBAC model.

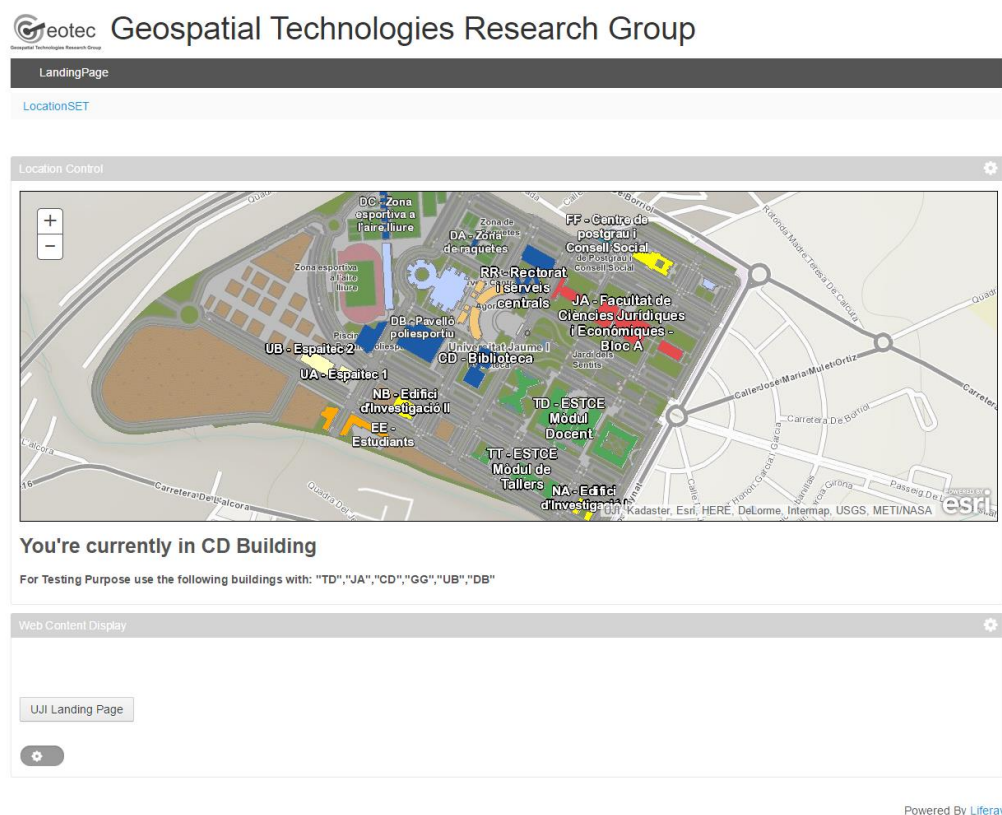


Figure 19: Manual Option to change the user's location

5 University Jaume I Smart Campus Portlet Applications

This chapter details about the portlet applications created as part of the prototype utilizing the location-based access control model Smart-RBAC. This location control access model has many benefits in the geospatial context, the applications created in this prototype exhibits the following:

- a. Customized Smart Campus UI: User-specific Behavior
- b. Liferay Customized Applications: User-specific Location-based Content Delivery
- c. Location Analytics: Aggregation of collected geographic information.

Note: Portal Application refers to the whole system, whereas portlet application refers to individual applications like customized smart campus, location analytics, etc.

5.1 Customized Smart Campus UI

We had discussed in the motivation part of the introduction chapter about the need to alter the behavior of the current Smart Campus UI [8]. With the help of the Smart-RBAC model, we can solve the problem by defining the smart campus application behavior for different kind of users. The objective of this application is to test the model Smart-RBAC to deliver different views of the smart campus application for different users.

5.1.1 Data

We had imported a subset of the existing smart campus UI and tried to test for the user-specific behavior. The layers are retrieved from the Smart Campus UI services of resources consumption and facilities. ArcGIS API for JavaScript [50] is used to import the layers into the page, for the 6 buildings defined in the scope of the portal application.

Subset of Smart Campus contains two perspectives:

- i. Energy
- ii. Facilities

Energy: the energy perspective contains 6 layers to be shown on the map, they are:

- i. Electricity Meters
- ii. Energy Consumption
- iii. Gas Meters
- iv. Gas Consumption
- v. Water Meters
- vi. Water Consumption

Facilities: The facilities perspective contains 5 layers to be displayed on the map, they are:

- i. Containers
- ii. Parking Points
- iii. Parking Areas
- iv. Buildings
- v. Facilities

5.1.2 Requirements

We have listed out some requirements that would utilize the user-specific behavior of the model (see figure 20). They are:

UJIAcademic: For a user who belongs to the UJIAcademic category, i.e. students and academic staff, both the perspectives of the portlet application, Energy and Facilities.

UJIMaintenance: For a user who belongs to the UJIMaintenance category, only the Energy perspective of the portlet application should be shown.

UJIVisitor: For all the visitors including the ones who registered, only the facilities perspective should be displayed on the map of the portlet application.

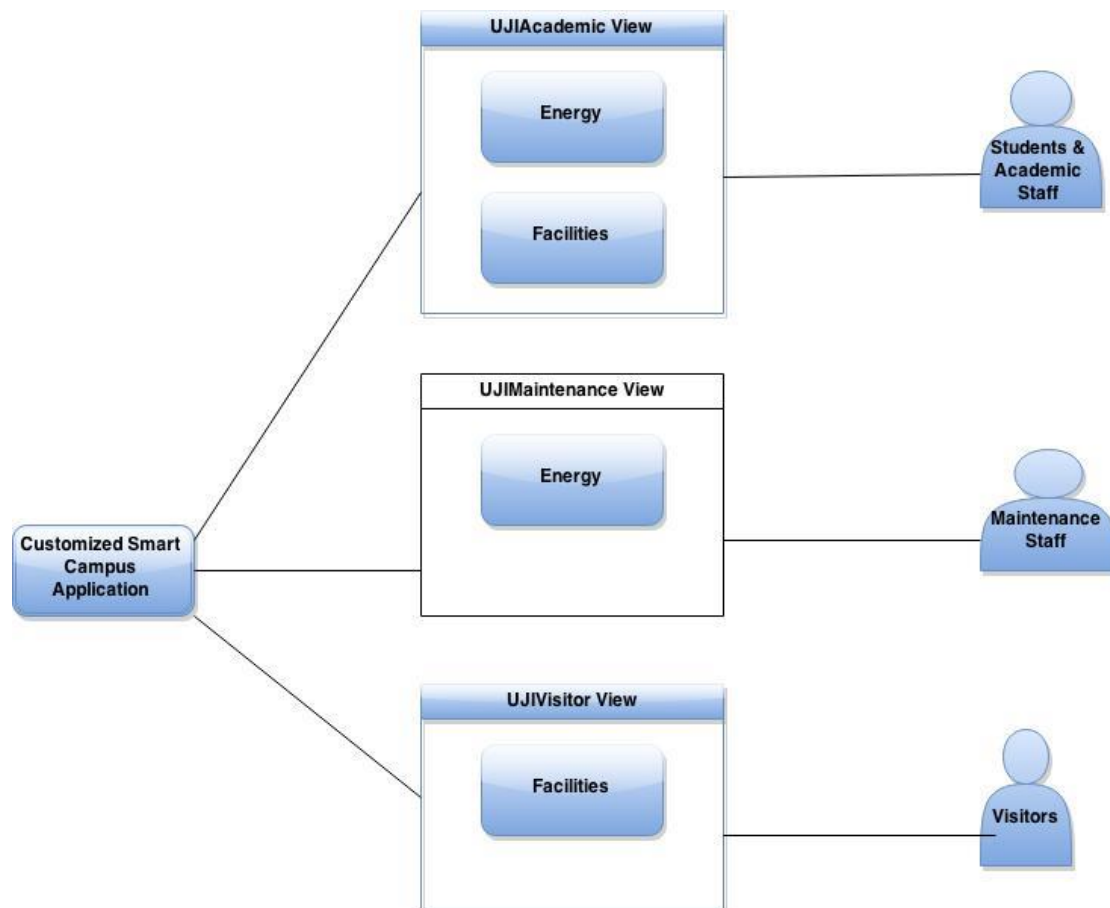


Figure 20: Different Views of Customized Smart Campus Application for different types of users.

5.1.3 Implementation

We created a portlet plugin “SmartCampusOrganizationRole-portlet” for fulfilling the above-mentioned requirements. The plugin contains business logic in “SmartCampuORPortlet.java” and UI components in “view.jsp”, “main.css”, “main.js” and “Infolayers.js”. The javascript code for displaying the energy and the facilities are borrowed from Smart Campus UJI application [8]. The Administrator and organization roles are assigned the permissions to view the portlet in the portal application.

5.1.4 Application Testing Scenarios

Scenario 1: Smart Campus Customized for a Visitor

Steps to recreate:

- i. We log in to the application as a visitor by clicking the option in the login page.
- ii. We select “Customized Smart Campus” in the landing page.

Observed Output: Only the facilities perspective is visible. This result satisfies the requirement for “UJIVisitor” users mentioned in “Requirements” section above (see figure 21).



Figure 21: Smart Campus with only Facilities perspective for Visitors

Scenario 2: Smart Campus Customized for Maintenance Staff

Steps to recreate:

- i. Login as Maintenance Staff member
- ii. Select “Customized Smart Campus” in the landing page

Observed Output: Only the Energy perspective is shown for the maintenance staff. This result fulfills the requirement for “UJIMaintenance” users mentioned in the “Requirements” section above (see figure 22).

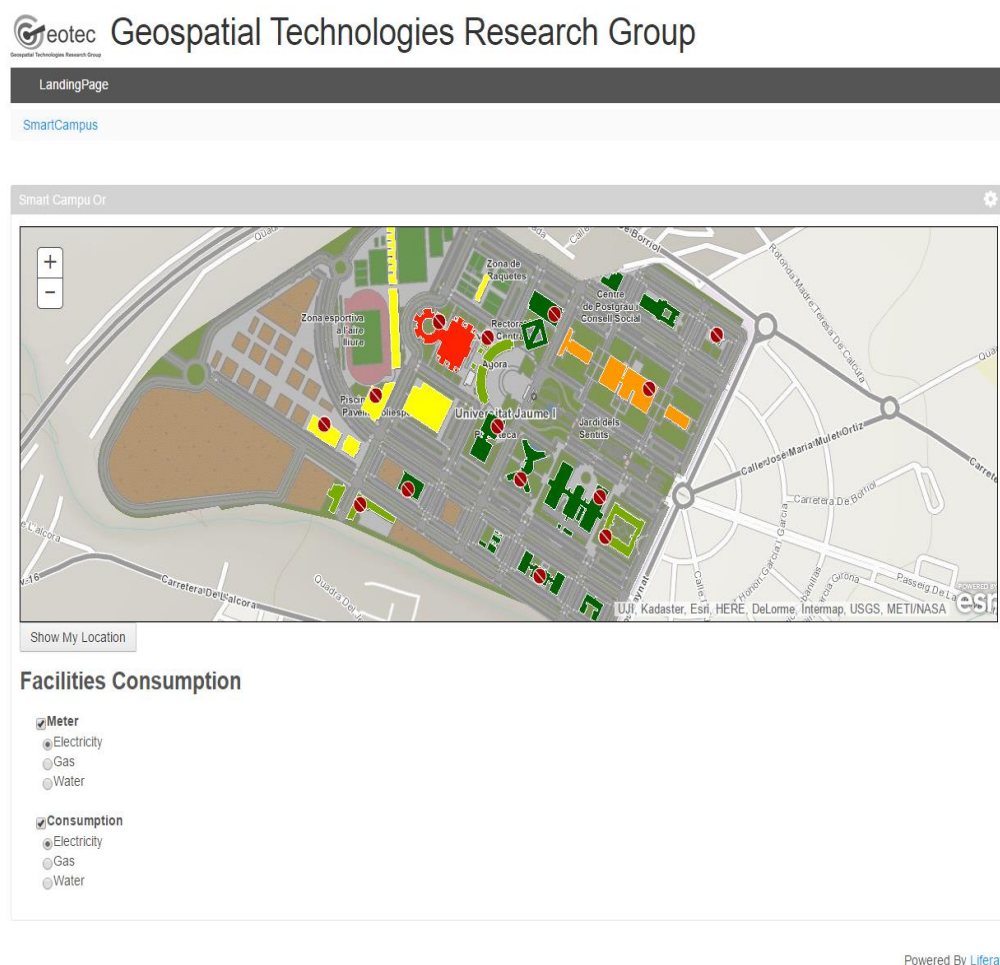


Figure 22: Smart Campus with only Energy perspective for Maintenance Staff

Scenario 3: Smart Campus Customized for Academic staff and students

Steps to recreate:

- i. Login as Academic Staff/ Student member
- ii. Select “Customized Smart Campus” in the landing page

Observed Output: Both the Energy perspective and Facilities perspective is shown for the academic staff and students. This result fulfills the requirement for “UJI Academic” users mentioned in the “Requirements” section above (see figure 23).

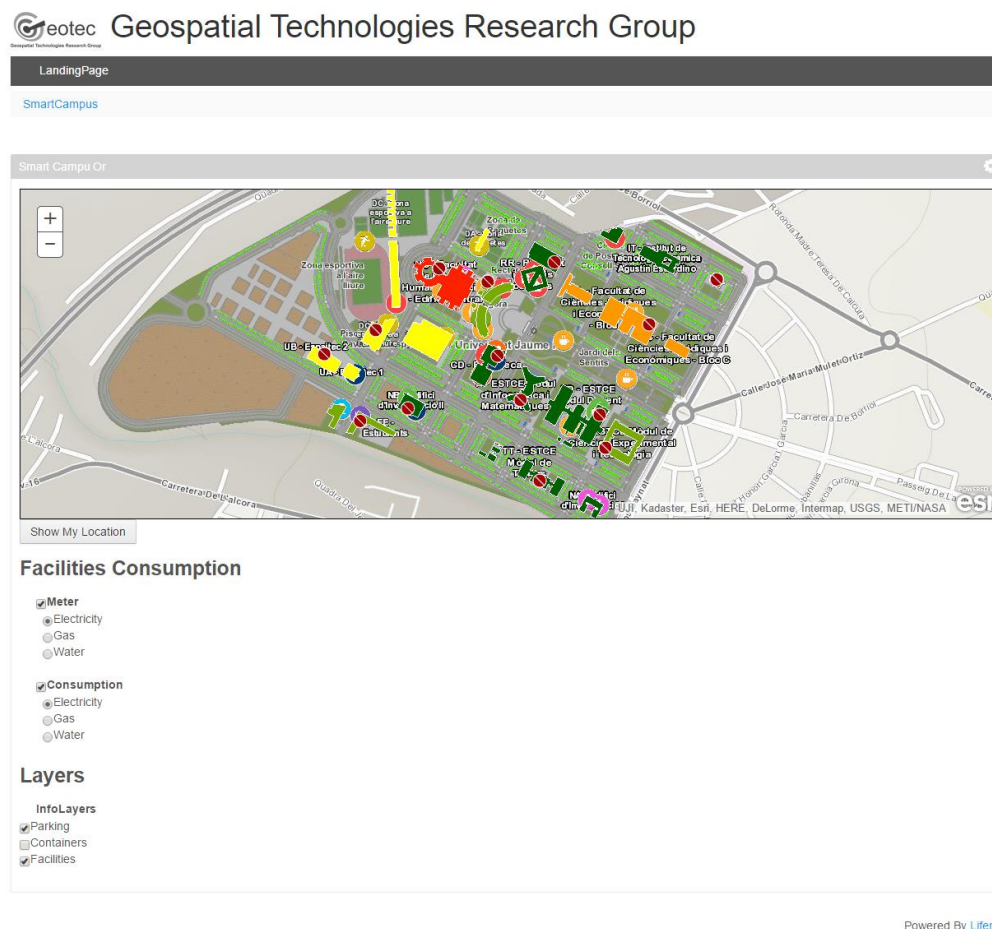


Figure 23: Smart Campus with both Facilities & Energy perspective for Academic Staff & Students

This portlet application validates the ability of the model to deliver services according to the user type. The portlet application can be scaled to include the entire Smart Campus UJI[8] and offers additional features to expand the reach of the existing application to the university community.

5.2 Customized Liferay Built-in Applications

Liferay Portal offers built-in applications [54] like Polls, Wiki, Message Boards, Calendar, etc. that can be plugged in directly to the portal application. However, we need to customize some applications to concur with our Smart-RBAC model. Apart from some part of the polls portlet, all the other applications are customized through the control panel of the “Administrator”.

These built-in applications are used to test the unique feature of the Smart-RBAC to deliver user-specific location-based content, corresponding to the objectives mentioned in the Introduction chapter. In this section, we discuss how Polls, Wiki and Message Board are accessible for different users in different locations. Furthermore, we will discuss the Polls portlet in detail to verify the variation of content according to user’s role and location.

5.2.1 Access to Liferay Built-in Applications

The below tables represents the access policy for the three applications Wiki, Message Boards and Polls. The access policy was defined with the purpose of testing the applications in different contexts. The Legend for the tables is as following (see table 1):

	Accessible
	Not accessible

Table 1: Legend for the Access policy of Liferay Built-in Applications

Wiki Application Access Policy:

		Location-Specific Roles					
	Wiki Application	JA	UB	TD	CD	DB	GG
User Role	UJIVisitor						
	UJIMaintenance						
	UJIAcademic						

Table 2: Access Policy for Wiki Application

The wiki application [4] can only be accessed if the user belongs to “UJIAcademic” role and the user’s location is either in “UB”, “TD” or “CD” buildings as shown in table 2.

Message Boards Access Policy:

		Location-Specific Roles					
	Message Board Application	JA	UB	TD	CD	DB	GG
User Role	UJIVisitor						
	UJIMaintenance						
	UJIAcademic						

Table 3: Access Policy for Message Boards Application

The message boards application [5] can only be accessed if the user belongs to “UJIAcademic” role and the user’s location is either in “UB”, “TD” or “CD” or “JA” buildings as shown in table 3.

Polls Application Access Policy:

		Location-Specific Roles					
	Polls Application	JA	UB	TD	CD	DB	GG
User Role	UJIVisitor						
	UJIMaintenance						
	UJIAcademic						

Table 4: Access Policy for Polls Application

The polls application [6] can only be accessed if the user belongs to “UJIAcademic” and “UJIMaintenance” roles as shown in table 4. The user’s location is used to vary the polls displayed on the page.

5.2.2 Wiki Portlet Application

Liferay has a built-in portlet application that “allows creation of contents in the Wiki Collaboration style” [4]. Unlike the traditional Wiki [55], Liferay Wiki offers additional functionality of assigning permissions to content in Wiki portlet. The users belonging to “UJIAcademic” present in buildings “TD”, “CD” and “UB” can create or edit articles in this Wiki portlet. However, we customized the process of approval to display the edited content or created content by the user. The Administrator approval (see figure 24) is required for the changes made by the user to be visible to other users of the Wiki Portlet.

Geospatial Technologies Research Group

LandingPage

UJIWiki

Wiki

Main UJI

FrontPage Recent Changes All Pages Orphan Pages Draft Pages

Search Search

Draft Pages

There are no drafts.

Pending Approval

Page	Status	Revision	User	Date
UJI Smart Campus	Pending	1.0	abc1	23 Seconds Ago

Categories Navigation

There are no categories.

Tags Navigation

There are no tags.

Identify Role By Location

Important Notice Regarding Your Location

Your current location is outside the campus. The role from your last session is being used to display location specific content. For changing your building specific content use the manual option

If you want to change your building group manually click on the below button

Change Location Manually

Link To Home Page

Go To Home Page

Powered By Liferay

Figure 24: Customized Wiki Portlet in Liferay showing pending draft pages.

5.2.3 Message Boards Portlet Application

Liferay portal offers a portlet to enable communication between members through an independent forum. Some of the important features are [5]:

- *Threaded Views*
- *Categories*
- *RSS Capability*
- *Avatars*
- *File Attachments*
- *Previews*
- *Dynamic List of recent posts*
- *Forum Statistics*
- *User Ranking*

The users belonging to “UJIAcademic” user role and in buildings “TD”, “CD”, “UB” and “JA” can create a thread or comment on a thread, etc. (see figure 25) Only the administrator has the permission to ban the members from posting in the forum. However, we can create Forum Moderators and assign them the authority to ban users.

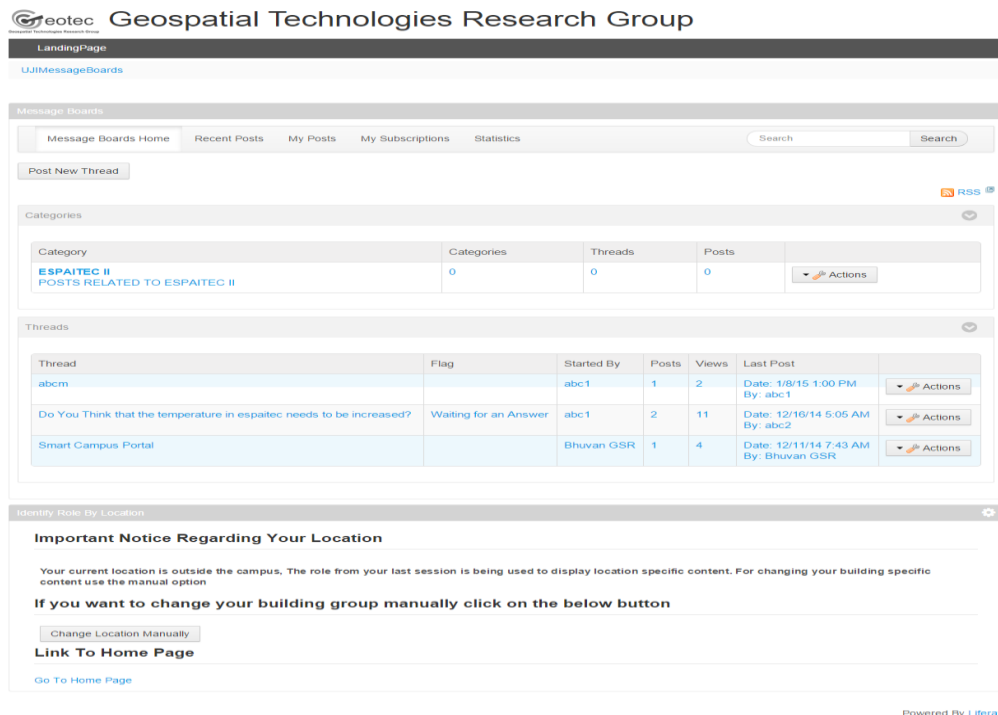


Figure 25: Message Board in UJI Smart Campus Portal Application

5.2.4 Polls Portlet Application

Polls Portlet [6] in Liferay is used by the users and the administrators to “create multiple choice polls” for the portal application users (see figure 26). The created polls are selected by the administrator to be displayed on the page using Polls Display Portlet [56]. The user can vote for the poll, only if it’s displayed on the page. Once the user votes for a particular poll, the statistics and results of the poll will be shown on the page.

The screenshot shows the 'Polls' portlet interface in Liferay. At the top, a blue header bar contains the text 'Geospatial Technologies Research Group / Site Administration' and navigation links for 'Admin', 'My Sites', and a user profile 'abc1'. Below the header, the portlet title 'Polls' is followed by a 'New Question' button. The form includes several sections: 'Title (Required)' with a text input field and a red error message 'This field is required.'; 'Polls Question (Required)' with a large text area; 'Expiration Date' with a date picker set to '02/28/2015' and a time picker set to '01:03 AM', and a checked checkbox for 'Never Expire'; 'Choices' with two input fields labeled 'a.' and 'b.', each followed by a row of flags; an 'Add Choice' button; and 'Permissions' with a 'Viewable by' dropdown set to 'Anyone (Guest Role)' and a 'More Options' link. At the bottom are 'Save' and 'Cancel' buttons.

Figure 26: Page to add polls with multiple choices

In the UJI Smart Campus Portal application, users belonging to “UJIAcademic” and “UJIMaintenance” user roles are eligible to access the Polls portlet Page. There are a number of polls present on the page, however, the polls specific to the location of the user will be shown. Thus, utilizing the benefit of Smart-RBAC model we alter the content of the page based on the user and location.

For Example: If a student moves from building “UB” to “CD” (see figures 27 & 28)

Geotec

Geospatial Technologies Research Group

LandingPage

UIIPolls

UI Polls Display

Question ID	Title	DeadLine	Creator
17709	DB Question	Wed Jan 21 19:31:20 GMT 2015	Bhuvan GSR
17706	JA Question		Bhuvan GSR
17701	Which Classroom makes more noise in TD Building?		abc2
17002	hello, is everything ok in UB	Wed Jan 21 20:12:04 GMT 2015	abc1
15214	Library Temperature	Tue Dec 16 11:25:21 GMT 2014	Bhuvan GSR
14482	Cafeteria	Wed Jan 21 20:16:25 GMT 2015	Bhuvan GSR

Polls Display

Which Cafeteria serves better food?
☐ a. Cafeteria, TD_ESTCE Modul Decent
☐ b. Automatic Restaurante, Agora Gallery
☐ c. Cafeteria, Economics Block A

Vote

Select Ques... Add Question

Polls Display

is everything ok in UB
☐ a. yes
☐ b. no

Vote

Select Ques... Add Question

Identify Role By Location

Important Notice Regarding Your Location

Your current location is outside the campus. The role from your last session is being used to display location specific content. For changing your building specific content use the manual option

If you want to change your building group manually click on the below button

Change Location Manually

Link To Home Page

Go To Home Page

Powered By Liferay

Figure 27: Polls page when user is in “UB” building

Geotec

Geospatial Technologies Research Group

LandingPage

UIIPolls

UI Polls Display

Question ID	Title	DeadLine	Creator
17709	DB Question	2015-01-21 19:31:20.0	Bhuvan GSR
17706	JA Question		Bhuvan GSR
17701	Which Classroom makes more noise in TD Building?		abc2
17002	hello, is everything ok in UB	2015-01-21 20:12:04.0	abc1
15214	Library Temperature	2014-12-16 11:25:21.0	Bhuvan GSR
14482	Cafeteria	2015-01-21 20:16:25.0	Bhuvan GSR

Polls Display

Which Cafeteria serves better food?
☐ a. Cafeteria, TD_ESTCE Modul Decent
☐ b. Automatic Restaurante, Agora Gallery
☐ c. Cafeteria, Economics Block A

Vote

Select Question Add Question

Polls Display

Do you agree to lower the temperature in Library building?
☐ a. Yes
☐ b. No

Vote

Select Question Add Question

Identify Role By Location

Important Notice Regarding Your Location

Your current location is outside the campus. The role from your last session is being used to display location specific content. For changing your building specific content use the manual option

If you want to change your building group manually click on the below button

Change Location Manually

Link To Home Page

Go To Home Page

Powered By Liferay

Figure 28: Polls page when user is in “CD” building.

There are two live polls on the page in the both occasions, however, the poll on the right changes according to the building as shown in figures 27 and 28.

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5.3 Location Analytics

With the location-based access control model Smart-RBAC, we use geographic location of the user to deduce his location-specific role. We store all the points collected during the usage of the portal application of the user. We aggregated this information into an EsriGeometryPoint [57] type feature layer and created a dashboard for monitoring movement patterns around the campus for the individual user and the Administrator.

5.3.1 Design

A dashboard tool has been developed to cater the requirement of the individual users and the administrator to track all the positions captured inside the campus. The tool offers data in real time where the user can see his last recorded position in the map. There are number of selection parameters. The general design of the application is described in the figure 29.

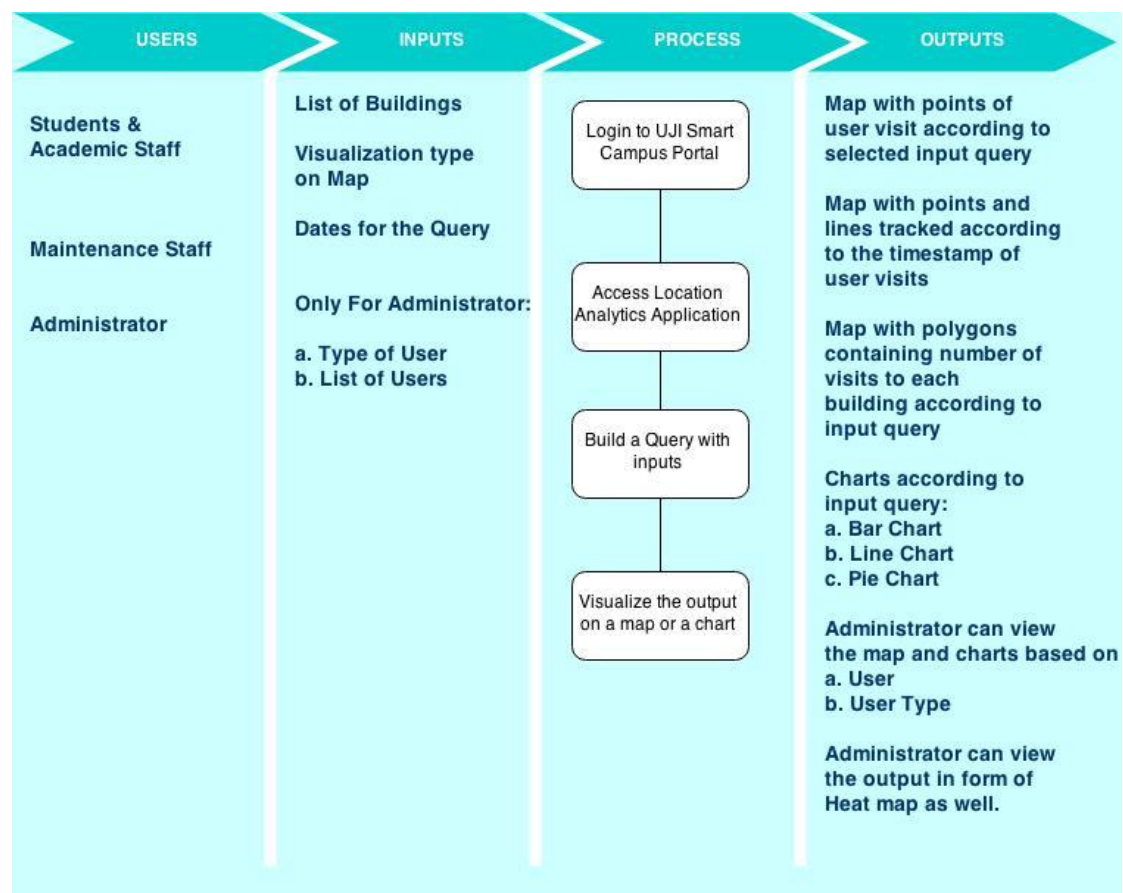


Figure 29: Design of the Location Analytics Portlet Application

Elaborating the figure 29, in the below section we describe the different components of the Location Analytics Portlet Application.

5.3.1.1 Users

The Location Analytics portlet application can only be accessed if the user belongs to the category of students, academic staff or maintenance staff. According to the UJI Smart Campus portal application, the user should belong to the category “UJIAcademic” or “UJIMaintenance”. The “Administrator” of the portal application can also access the portlet application.

The Location Analytics portlet application behavior varies for the UJI users and the “Administrator”. The “Administrator” has more functionality than the normal user, however, the “Administrator” cannot track the path of movement of individual users.

5.3.1.2 Inputs

The Application has the following list of inputs for Normal users:

List of Buildings: This list contains the buildings “JA”, “TD”, “CD”, “DB”, “UB” and “GG” in the form of checkboxes. We can select a minimum of one and a maximum of 6 buildings for creating the query.

Type of Visualization: The application provides the option of choosing the type of visualization to either points or polygons. If we choose points, then the result of the query, i.e. the user visits will be displayed as points on the map. Otherwise, if we choose polygons, then the result of the query, i.e. the user visits, will be aggregated based on the building and shown as number of visits to each building in the campus. This parameter is not applicable while generating charts.

Time Period: Selecting time period is an optional input parameter. The user or Administrator can specify the time period for the query to retrieve the user visits in the form of a map or a chart during the selected time period.

Additionally for the “Administrator” the following inputs are provided:

Type of User: The Administrator has the option to select the type of user, like “UJIAcademic”, “UJIMaintenance” and “UJIVisitor”. If the Administrator selects either of “UJIAcademic” or “UJIMaintenance”, then the list of users input parameter is shown. The default value of this input parameter is “All Types of Users”, as the name suggests includes all the users.

List of Users: This input parameter is shown based on the selection of the “Type of User” parameter. If the “UJIAcademic” is selected as the “Type of User”, then the list of users contains only the users of “UJIAcademic” category, with “All Academic Users” as the default value. Similarly, when “UJIMaintenance” is selected as the “Type of User”, then the list of users contains only the users of “UJIMaintenance” category, with “All Maintenance Users” as the default value.

5.3.1.3 Process

The Location Analytics Portlet application follows the workflow presented in figure 29. The user or Administrator will first login to the UJI Smart Campus Portal Application and access the “Location Analytics” page from the landing page of the portal application. In the “Location Analytics” page, the user or the Administrator will build the query based on their choice of input parameters and chose to visualize the output on the map or as a chart.

5.3.1.4 Outputs

The outcomes of the application can be categorized broadly into two main categories of visualization such as map and chart. The outcomes visualized on the map can be categorized into two categories as well, like points and polygons. The outcomes visualized as the following types of charts namely pie chart, line chart, bar chart, column chart.

As mentioned earlier, the application behaves differently for the “Administrator” and a normal user. The below section highlights the differences by listing out the different types of outcomes with regard to the normal user and the “Administrator”.

Normal User: UJIAcademic or UJIMaintenance User

Outcomes Visualized as points on Map:

- Historical data of all the visits of the user
- Historical data of user visits to selected buildings
- Data of all the visits during the selected time period
- Data of user visits to selected buildings during the selected time period

Outcomes Visualized as polygons on Map:

- Historical data about the number of visits to the selected buildings
- Data about the number of visits to selected buildings during specific time period

Outcomes Visualized as charts:

- Number of visits to different buildings
- Number of visits to different buildings during selected time period.

Additional Outcomes:

- The users’ visits on the map are tracked with line feature according to the timestamp of each visit.

Administrator:

Outcomes Visualized as points on Map:

- Historical data of all the visits of all the users
- Historical data of selected user visits to selected buildings
- Data of all the visits of selected type of users to selected buildings

- Data of all the visits of selected type of users during the selected time period
- Data of selected user visits to selected buildings during the selected time period

Outcomes Visualized as polygons on Map:

- Historical data about the number of visits to the selected buildings of selected user type
- Data about the number of visits to selected buildings of selected user type during specific time period
- Historical data about the number of visits to the selected buildings of selected user
- Data about the number of visits to selected buildings of selected user during specific time period

Outcomes Visualized as charts:

- Historical data about the number of visits to the selected buildings of selected user type
- Data about the number of visits to selected buildings of selected user type during specific time period
- Historical data about the number of visits to the selected buildings of selected user
- Data about the number of visits to selected buildings of selected user during specific time period
- Column charts for number of visits against the date of visits for all users with regard to a selected building.
- Column Chart regarding number of visits by each user for a selected building

Additional Outcomes:

- Heat Map displaying the density of all the visits on the map

5.3.2 Implementation

A portlet plugin is developed to create this application named “UserLocatioActivityPortlet” with a portlet “UserLocatioActivityPortlet.java” as controller and “view.jsp” along with “main.js”, “toolAdminSp.js” and “main.css” as UI Component. The dashboard application is predominantly coded in JavaScript, with the map functionality imported from ArcGIS API for JavaScript [50]. The heat map has been rendered using the feature layer service named “UserLocationTracking”, hosted in smart campus UJI [8] ArcGIS Server⁷ created for the application. We use Google Charts JavaScript API¹² to generate charts for this application. The tests performed on this portlet application are documented in Appendix A and the links for the code in Appendix B.

Example Queries:

1) Query 1

Data:

User category	UJIAcademic
Selected buildings	All
Type of Visualization	Points
Time Period	Jan 1 st , 2015 – Feb 6 th , 2015

Table 5: Data for Location Analytics tool query 1

The aforementioned data is chosen in the location analytics tool of the UJI Smart Campus Portal application. The user then clicks on “Show on Map” button to retrieve the output.

¹² <https://developers.google.com/chart/> [Last Accessed on Jan 28th , 2015]

Query 1 Output:

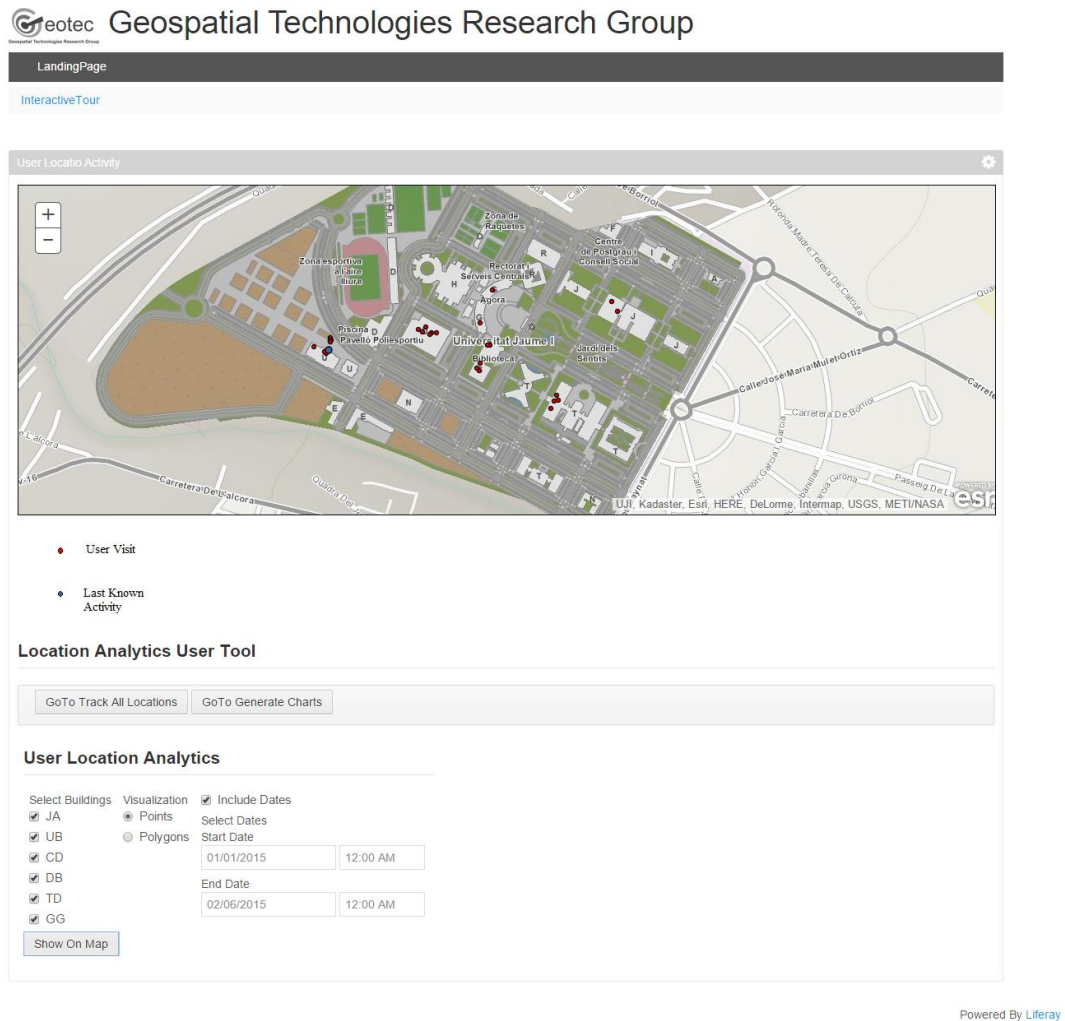


Figure 30: Outcome of the example query 1.

2) Query 2

Data:

User	Administrator
Selected buildings	All
Type of Visualization	Points
Time Period	Jan 1 st , 2015 – Jan 29 th , 2015
List of Users	All Academic Users

Table 6: Data for Location Analytics tool example query 2

The aforementioned data is chosen in the location analytics tool of the UJI Smart Campus Portal application. The user then clicks on “Show on Map” button to retrieve the output and the “Generate Heat Map of all Visited Points”.

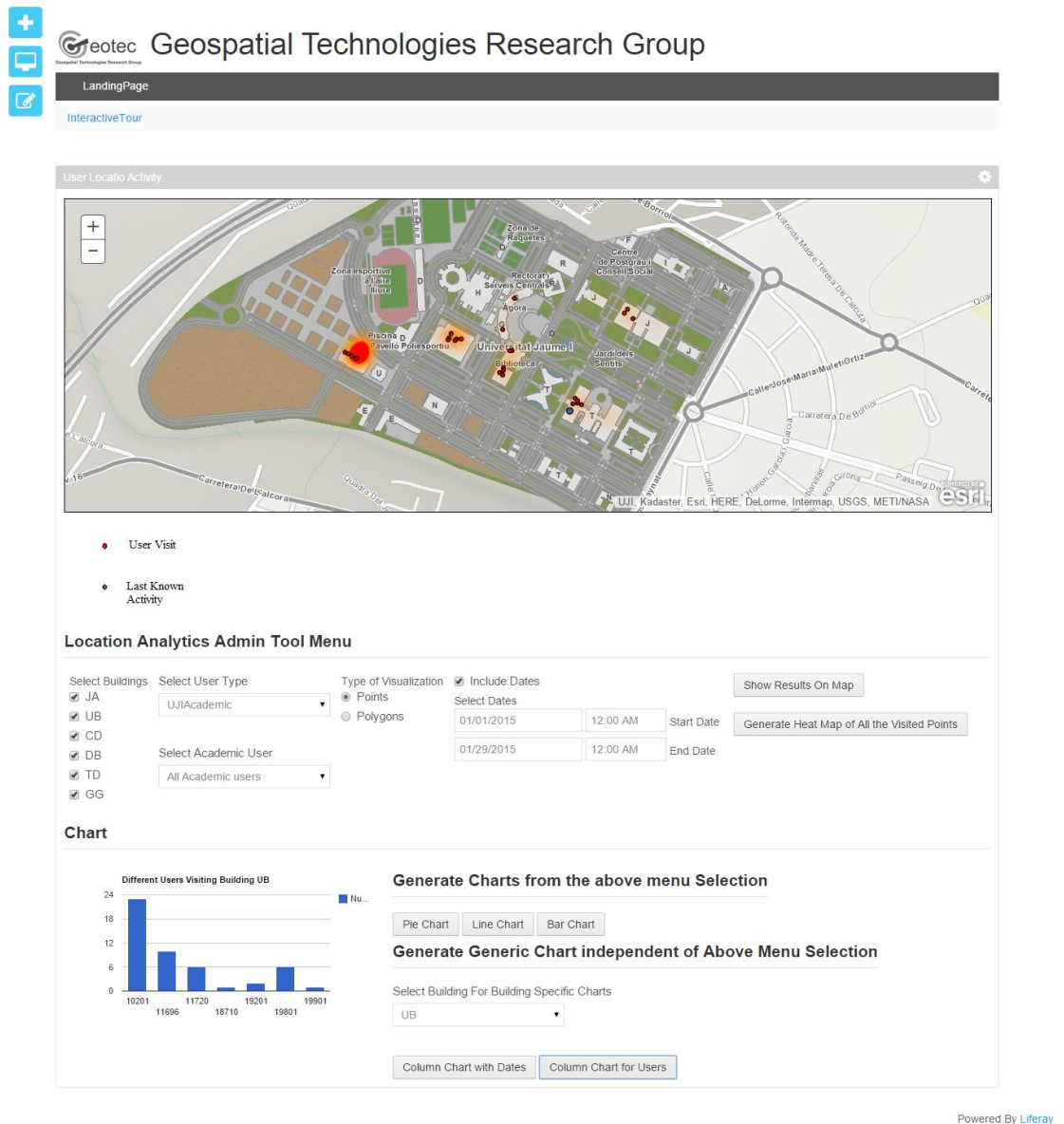


Figure 31: Outcome of the example query 2

6 Evaluation and Discussion

6.1 Evaluation

This Chapter details the evaluation procedure followed to test the Smart-RBAC model against the access control model goals.

6.1.1 Achievement of Access Control Goals

In [7], authors propose a “theoretical framework” for evaluating location-based access control models with regard to “goals, systems and context”. We use this proposed procedure to evaluate our Smart-RBAC model on the basis of the criteria mentioned in the paper [7]. We are mainly concerned about the “achievement of goals” in this section. We conducted tests on the UJI Smart Campus portal application that implements Smart-RBAC model to verify the “achievement of goals”. The five goals specified in [7] are “Separation of Duty”, “Least Privilege”, “Accountability”, “Maintainability” and “Usability”. In the section below, we are going to evaluate the Smart-RBAC model against each goal listed above.

6.1.1.1 Separation of Duty

Separation of Duty is a security principle that involves two or more people to complete a work [33]. There are two kinds of separation of duty:

Static Separation of Duty: To achieve static separation of duty, we need to follow the rule that conflicting roles should not be assigned to the same user. Our model Smart-RBAC does not achieve this goal as a single user is eligible to be assigned to all the location-specific roles, even though some of them has conflicting permissions assigned to them.

Dynamic separation of duty: To achieve dynamic separation of duty, we should adhere to the rule that conflicting roles should not be assigned to the same user simultaneously. This goal can be achieved by the Smart-RBAC model. To validate the claim, we perform a test on the prototype application UJI Smart Campus Portal, which implemented the Smart-RBAC model. The details of the test are given below.

Dynamic Separation of Duty Test details

Test requirement: The portal application user should be able to access the “Wiki” portlet application [4] if and only if the user’s location-specific role is “CD”, “UB” or “TD”. For the other location-specific roles like “JA”, “DB” and “GG” we should be able to access “Wiki” portlet application.

Test Precondition: The user should be a registered user belong to the University Jaume I academic community. In technical terms, the user should belong to the “UJIAcademic” category. The user can either move or use the manual option to change the location-specific roles.

Initial Condition: The user belongs to “UJIAcademic” category. His current location-specific role is “CD”, therefore he has the access to “Wiki” Application, as shown in figure 32.

Note: Liferay³ RBAC does not support the feature of separation of duty [27]. Therefore, the location-based access control model Smart-RBAC improves the security features of Liferay RBAC



Figure 32: The user has access to “Wiki” application as his location-specific role is “CD”

Test steps:

The user moves from building with buildingId “CD” in the UJI campus to building with buildingId “DB”

(Or)

The user navigates to the Manual change option and changes his location-specific role to “DB”

Test Output:

The user with location-specific role “DB” cannot access “Wiki” Portlet application as shown in figure 33.

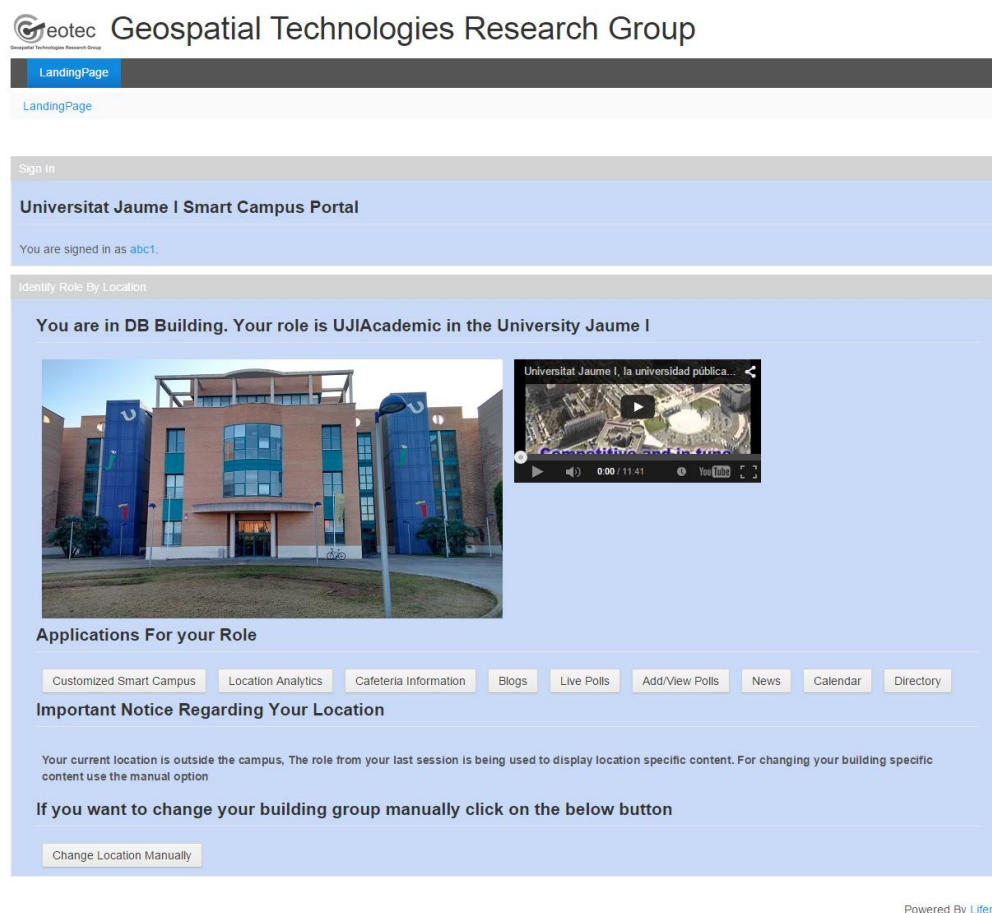


Figure 33: The user does not have access to “Wiki” application as his location-specific role is “DB”

Inference:

This test verifies that the Smart-RBAC model achieves the goal of “Dynamic Separation of Duty”. Assigning roles to the users based on their location principle has helped in achieving this goal.

6.1.1.2 Least Privilege

According to this principle, users will be granted permissions or assigned roles to access resources only if they are necessary [33]. Creating an application with this principle will help to overcome certain risks like:

- Unnecessary authorizations can be controlled
- User will not be assigned role to access resource that is forbidden to access
- Impersonation of User

The Smart-RBAC model needs information about the necessary authorizations for each user to implement this principle. The prototype application did not conduct a study for identifying necessary permissions to assign to a user to control unnecessary authorizations. However, with the principle of assigning only one location-specific role to the user at any given point would restrict to some extent the irrelevant permissions to the users. Therefore, the prototype application implementing Smart-RBAC cannot be used to test the goal of achieving “Least Privilege”. Assuming that the necessary permissions for the roles are known then, we can say that Smart-RBAC model can help to achieve the goal of “Least Privilege”.

6.1.1.3 Accountability

As we do not know the exact permissions to assign to roles to achieve “Least Privilege”, we will monitor users’ interaction with the application and log the information about the interaction. The users will be held responsible for the actions performed through their account. This is a security principle to restrict fraudulent activities in the system. Our Smart-RBAC model does not enforce the user to change his/her physical location to change his/her location-specific role to access the content or to modify the behavior

of the application. Therefore, identifying anomalies in the usage of the application for a particular user related to his/her physical location is difficult to achieve.

However, we monitor the location of the user every one minute and log the location along with the name of location-specific role, timestamp, user type and UserId. Moreover, we have a location analytics dashboard that displays the logged feed of the user's movement. Therefore, to check for the anomalous activity we can check for the time difference between subsequent location-specific role changes. If the difference is too low, then we can mark it as a fraudulent activity as the normal transit time between two locations is far greater than the time difference. The Administrator performs this process and will revoke the access permissions for the user's account.

For example, a case of fraudulent activity is shown in the table 7 that describes the location-specific role change event of a user with "UserID" 18531, when he moves physically from building "UB" to building "JA". The time difference between the visited times of both the buildings is around 6 seconds, however in reality the distance between the two buildings is 850 meters that would take around ten minutes to traverse (see figure 34) according to Google Maps¹³.

UserID	Location-Specific Role	Organization Role	Visited Time
18531	UB	UJIAcademic	Tue, 10 Feb 2015 07:01:27 GMT
18531	JA	UJIAcademic	Tue, 10 Feb 2015 07:01:33 GMT

Table 7: Example of fraudulent activity

¹³ <https://www.google.es/maps> [Last Accessed on Feb 10th , 2015]

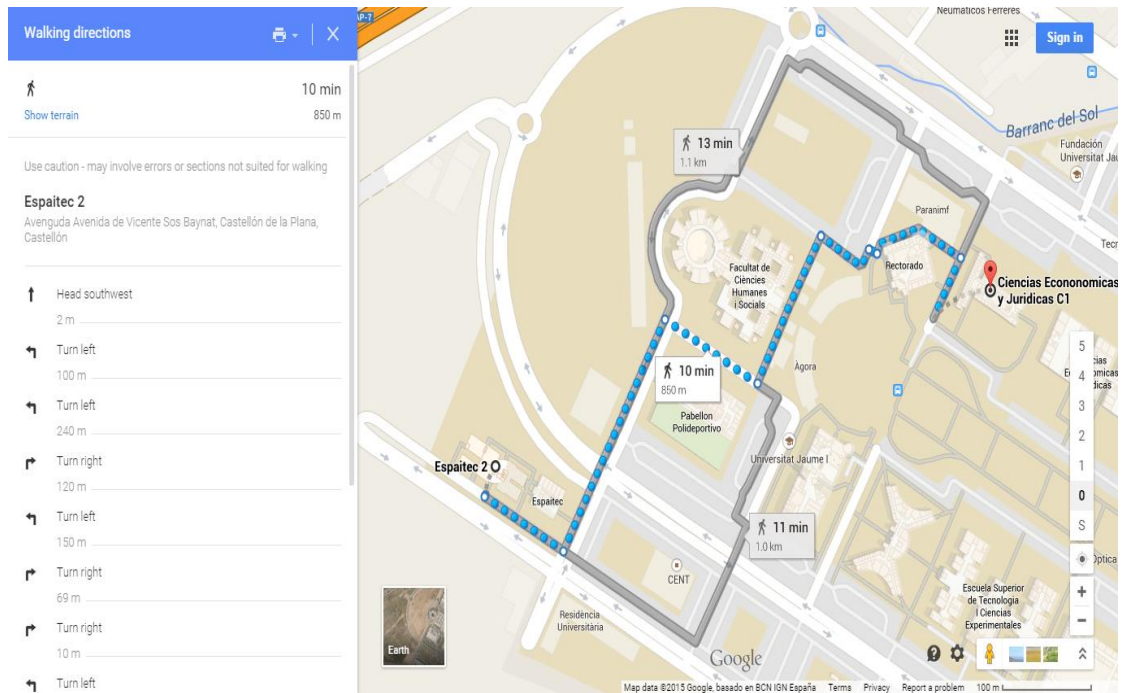


Figure 34: Distance between UB building and JA building according to Google Maps

6.1.1.4 Maintainability

Inability to identify the necessary actions and permissions that need to be assigned to achieve “Least Privilege” requires us to maintain the record of the roles and permissions assigned to different users according to their user type. The Smart-RBAC model does not help to achieve this goal as the roles are assigned to users. Generally, the role of a user changes multiple times in a user session which creates multiple records in the database. To improve maintainability we need to follow the concept of one role with varying permissions according to location [7].

6.1.1.5 Usability

The goal of Usability can be achieved by reducing the complexity of the model and its usage. Though Usability test is not performed on the Smart-RBAC model, we believe that it achieves the goal partly, by requesting permission from the user to change the location-specific role of a user and by relaxing the rule of physical presence in a location to change his/her location-specific role to the desired location. The model provides a

manual option to change to a desired location-specific role for the user. We need to perform a user study to analyze the usability level of the model qualitatively. The tests performed on the prototype are documented in Appendix A.

The evaluation results with respect to the achievement of security goals are compiled in the table 8.

6.1.2 Limitations

The evaluation procedure followed in this section primarily focuses on the Smart-RBAC model's capability for achieving the security goals. Though these security goals are a standard for evaluating access control models, there are some limitations to the evaluation method used. Firstly, the method does not evaluate the content that is being delivered to the user based on his/her role and location. It does not verify whether the delivered content is appropriate or not to the user. A user survey is needed to figure out the appropriate content for a particular role and location in the smart campus. Secondly, the evaluation procedure followed does not assess the feature of roles hierarchy in the organization roles of the Smart-RBAC model. Though, the model does not offer hierarchy in the location-specific roles, it offers hierarchy in the organization roles of the smart campus. Finally, the benefits of using the model in a university context are not evaluated as part of the evaluation. The benefits of the Smart-RBAC model in the university environment were discussed in the chapter *University Jaume I Smart Campus Portlet Applications*.

Security Goal	Achievement Status	Comments with respect to Smart-RBAC Model
Static Separation of Duty	Not Achieved	Conflicting roles can be assigned to the same person according to the Smart-RBAC model, which should not be the case.
Dynamic Separation of Duty	Achieved	Conflicting roles cannot be assigned to the same person simultaneously, as only one location-specific role is allowed at any point of time
Least Privilege	Not Achieved	Further studies are required for acquiring the knowledge of necessary authorizations for different users in the university environment.
Accountability	Achieved	We can monitor anomalies of user's usage or fraudulent activities with regard to the position.
Maintainability	Not Achieved	Though role change events and permissions are recorded in the database, there are chances that the user role changes multiple times in a single session, thereby maintenance is difficult to achieve.
Usability	Partly Achieved	Flexibility offered to users by empowering them with the authority to manage location-specific role changes and by removing the restriction of physical presence to access content. User study needs to be performed to confirm the model's ability with respect to this goal.

Table 8: Achievement of Security Goals for Smart-RBAC model

6.2 Discussion

This section weighs the choice made to design the Smart-RBAC model and details the potential pitfalls of the model. Apart from the aforementioned details the chapter elaborates the difficulties during the implementation phase of the prototype portal application UJI Smart Campus Portal.

We made two important choices that differentiate Smart-RBAC model with the other location-based access control models. They are: permission from the user to change location-specific role and a manual option to change the location-specific role of the user.

The first choice of waiting for user's permission to change the location-specific role is made to assert more control to the user. This choice helps in holding user accountable for the location-specific role change process. The choice is primarily made to avoid the unnecessary role changes when a user passes near to buildings. There would be a cluster of notifications in user's homepage, whenever a user roams around campus if this choice of permission from the user is not made for designing the model. A better alternative would be to automatically assign location-specific roles with consideration of time period between consecutive location-specific role change events and the speed of the user's transit. However, further research should be done to assess the feasibility of this option.

The second choice of providing manual option to change the location-specific role is made to reduce the burden on the user to move physically to different locations, to be eligible for those location-specific roles. Though, security of the application is at risk, considering the main objective of the model is to deliver content, therefore the usefulness of this choice was considered more important than security. However, if there are restrictions on accessing some content only in some physical location then we need to disable the manual option.

Apart from the functionality of appropriating content according to location and user type, the model has the potential to enable the user with the following information that could benefit the user. Firstly, the captured location information can be used for improving the management of the organization's resources. For example in the case of the university, we often notice the problem of crowding in libraries during the examination period. The authorities should consider benefitting regular users of the library with guaranteed space instead of allocating equal space to everyone. However, the information about a particular user's visits to the library is not known to the authorities to take necessary action. This model captures details about the user's movement around the campus which would be useful to derive this sort of information. In fact, the "Location Analytics" application of the prototype fulfills these kinds of requirements by providing information in a visual format, like maps and charts.

Secondly, the model can be used to strengthen security features, for example, we can define boundaries for the examination hall for an Intranet-based exam. Therefore, the student has to be present in the examination hall physically to attend the exam.

6.2.1 Potential Pitfalls

The model works on the assumptions that the user always shares his/her location. This might not be the case always due to user's privacy concerns. Though the manual method of choosing location-specific role might be of use in these cases, the model might not achieve its objective of user-specific location-based content delivery.

The model does not consider cases where the user location might be in the vicinity of two or more buildings. The model fails to deduce appropriate role, instead it just allocates the role to a random building in the vicinity.

The model relies on the base RBAC model that it extends for different components like User, Session, Permissions, Role. Therefore there lies a risk of over-dependency on the base RBAC model. The model does not allow hierarchy in location-specific roles, where spatial relationships between the objects are present. For example, a user cannot

be assigned both the building and room's location-specific role. Therefore, this model is not useful for finer granularity of rooms in a university campus with spatial hierarchy.

6.2.2 Difficulties in Implementation of Application

We chose Liferay¹ Portal Server to build our UJI Smart Campus Portal application as it is open source and contains in-built Role-based Access Control (RBAC) system. Liferay portal server has in-built applications that can be customized for verifying the model's functionality like Polls, Message Boards, Wiki, etc. Portal server supports portlets, a pluggable web components that can be deployed independently in the portlet container. Therefore, adding or removing functionality to the application is very simple and does not require much time. ArcGIS API for JavaScript [50] and AJAX⁸ are used to call the Smart Campus UJI [8] services as they are easy to implement, especially ArcGIS API for JavaScript as it conforms with the RESTful web services [49] hosted in the ArcGIS server of Smart Campus UJI . We used Google Charts JavaScript API to generate charts as it's easy to integrate and an open source API.

The technical difficulties posed to us while creating the portal application are as following:

- It was difficult to identify the equivalent of Smart-RBAC location-specific role and a role type in existing Liferay RBAC. After many days of code walkthrough and design walkthrough coupled with trial and error methods, we zeroed in on the "Site role" of the Liferay RBAC.
- There is not much documentation available for developing location-based access control based on an existing RBAC model. Therefore, everything had to be developed with intuitive design and thorough testing.

7 Conclusions and Future Work

7.1 Conclusions

In this thesis, we aimed to propose a location-based access control model to achieve the objective of delivering user-specific location-based content. Additionally, we studied the behavior of the proposed model when applied to existing Liferay's RBAC by creating a portal application consisting of different portlet applications. Furthermore, we sought to evaluate the proposed model based on the "extent of achievement of goals" of location-based control models as mentioned in [7]. The literary review of work done on location-based access control models focuses primarily on strengthening security of the context-aware applications but not so much on the flexibility required for the user in a content delivery application. The model was proposed, Smart-RBAC, to offer comparatively higher flexibility to applications delivering user-specific location-based content.

The model was found useful in a university environment to authorize access to different types of users based on their current location. With the help of a prototype application, we validated the following objectives mentioned in the first chapter "Introduction":

- We proposed a model Smart-RBAC to deliver location-specific content relevant to different types of users in a university environment.
- The model Smart-RBAC extends the existing Liferay RBAC and achieves goals like dynamic separation of duty and accountability [7].
- Portal Application "UJI Smart Campus Portal" has been created to implement the proposed location-based access control model.
- Applications like "Customized Smart Campus" and "Customized Liferay Built-in applications" proves the usefulness of the model in a campus environment.
- "Location Analytics" application is developed to utilize the location information collected during users' interaction with the portal system.

We observed that the choices made during the design of the model like requesting for permission to change the location-specific role and a manual option for the location-specific role change, enhanced the extent of control a user can assert on the system. Though, many security features of other Location-based Access Controls (LBAC) are compromised for the convenience of the user, yet some of the goals of a typical location-based control model [7] are achieved like “Dynamic Separation of Duty” and “Accountability” and the goal of “Usability” is achieved partly. The evaluation of the prototype application proved that the proposed model improves the security features of the base RBAC model, in this case Liferay RBAC model.

The geographical extent of location-specific roles in the prototype application is limited to the buildings in the campus of University Jaume I. Though, the model is successful in achieving the objective at this coarse level of spatial resolution, model needs to be tested for finer lever of spatial resolution like rooms, etc. Due to the lack of hierarchy in the location-specific roles of the Smart-RBAC model, hierarchical spatial relationships between entities cannot be modeled.

The model can be extended to include many features that are discussed in the next section titled “Future Work”.

7.2 Future Work

The Smart-RBAC model proposed in this thesis needs to be tested in more scenarios to validate its usefulness in different scenarios. The different types of testing and scenarios for testing are:

Usability Test: We need to test an application created by implementing Smart-RBAC model like UJI Smart Campus application with different sets of users in different locations to assess the usability of the application and the model.

Performance Test: As the model involves in the creation of the specific role for each location, we need to assess the model's capability of handling multiple users in multiple locations.

Test Scenarios: The current application assigns the location-specific role with large geographic extent like buildings, we need to test for the model's ability to perform for smaller geographical extents like rooms. The prototype application customized a subset of the UJI smart Campus for evaluating the benefit of the model, however it needs to be scaled to include the entire smart campus application.

There is a lot of work going on in the area of location-based access control, we need to extend our Smart-RBAC model to improve the security and usefulness.

- Smart-RBAC with support for spatial relationships: If spatial relations exist among the location- specific entities or roles we need to consider them into the model.
- Smart-RBAC with support for other contextual attributes:
We need to extend our model to provide support for contextual attributes other than the location. For example, attributes like temperature, time could be useful for assigning roles in combination with location.

Apart from these, the alternative for the “permission to change location-specific role” option provided by the model needs to implemented considering the time period between consecutive location-specific role change events and the speed at which the user navigates around the university campus. This would help us to classify the scenarios that need the user's authorization and the cases where location-specific role can be automatically assigned.

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Appendix A: Tests

This appendix gives an account of the tests performed on the prototype application to validate and evaluate the Smart-RBAC model. The tests are categorized into different events in the workflow of the application. The categories are: *Creating an account, Logging into prototype application, assignment of location-specific role according to user's physical location and manual location-specific role change option*. Furthermore, we showcase different outcomes of the *Location Analytics* application, by altering the inputs of the tool. There will be a brief description the tests in this appendix and the corresponding screenshots will be shown as outputs.

Creating an Account:

As discussed in the Prototype chapter, there are three types of users in UJI Smart Campus portal application namely, UJIAcademic, UJIMaintenance and UJIVisitor.

The users of university, UJIAcademic and UJIMaintenance, are needed to create an account, however, this rule is not enforced on the visitors of the university, UJIVisitor. The visitors have the option to access the portal application by registering as a user or without registering. Therefore, we have two scenarios for creating an account in the UJI Smart Campus portal application, Visitors and UJI members.

Creation of account for Visitors:

The visitors who opt in to register to the application will be shown this page. The link to this page is displayed on the login screen (see fig a). The visitor would then provide the personal details like the first name, last name, date of birth, gender, email address and preference details like the screen name (see fig b). When we click on “Save” button in this page, a new account will be created and the password will be shown on the page (see fig b).

Test Data:

First Name:	VisitorUJI
Date of Birth:	01/01/1989
Gender	Male
Email Address	VisitorUJI@gmail.com

We use the user first name as Screen name.

Test Steps:

1. We click on the link “Visitor? Do you want to Register? Click here”

Geotec Geospatial Technologies Research Group

LandingPage

Sign In

Universitat Jaume I Smart Campus Portal

UJI Portal Sign In

Screen Name This field is required.

Password

☐ Remember Me

[Sign In](#)

For Visitors of UJI

[To Access Without Registering](#)

[Visitor? Do You Want to Register? Click Here](#)

For Univerity Jaume I Users

[Create Account](#) [Forgot Password](#)

Powered By Literay

Fig a: Login page with the link to register for visitors

2. We will fill the form in the create account page with the details of the visitor and click on the “Save” button.

Geotec Geospatial Technologies Research Group

LandingPage

Create Account [Return to Full Page](#)

First Name (Required)
VisitorUJI

Birthday
01/01/1989

Middle Name

Gender
Male

Last Name

Screen Name (Required)
VisitorUJI

Text Verification (Required)
6233

Email Address (Required)
VisitorUJI@gmail.com

Save

[Sign In](#) [Forgot Password](#)

Powered By Liferay

Figure b. The details of the visitor are entered to create an account.

3. Note down the password (highlighted) shown on the screen to login.

Geotec Geospatial Technologies Research Group

LandingPage

Sign In [Return to Full Page](#)

Universitat Jaume I Smart Campus Portal

UJI Portal Sign In

Thank you for creating an account. Your password is 77*11, Your password has been sent to visitoruji@gmail.com.

Screen Name
visitoruji

Password

☐ Remember Me

Sign In

For Visitors of UJI

To Access Without Registering
Visitor? Do You Want to Register? [Click Here](#)

For Univerity Jaume I Users

[Create Account](#) [Forgot Password](#)

Powered By Liferay

Figure c: Registration successful and the password is shown

Validation: We checked in the database whether the user account is created. The result is shown below with a UserID of 20001.

```
mysql> select * from user_ where firstName="VisitorUJI";
```

uuid_	userId	companyId	createDate	modifiedDate	defaultUser	contactId	password_	passwordEncrypted	passwordReset	passwordModifiedDate	digest	reminderQueryQuestion	reminderQueryAnswer	graceLoginC	ount	screenName	emailAddress	facebookId	ldapServerId	openId	portraitId	languageId	timeZoneId	greeting	comments	firstN	ame	middleName	lastName	jobTitle	loginDate	loginIP	last	LoginDate	lastLoginIP	lastFailedLoginDate	failedLoginAttempts	lock	out	lockoutDate	agreedToTermsOfUse	emailAddressVerified	status	
2efd2950-78c6-4057-a783-3001624e6c15	20001	10157	2015-02-11 11:47:30	2015-02-11 11:47:30	0	20002	AAAAoAAB9AA+TC2aXsTBLdgZvopvDDNXL/v8H3gm9pv+UDAv	1	0	2015-02-11 11:54:24		what-is-your-father's-middle-name	a		0	visitoruji	visitoruji@gmail.com	0	-1			0	en_US	Europe/Paris	Welcome VisitorUJI!		VisitorUJI				2015-02-11 11:54:15	127.0.0.1	2015-02-11 11:54:15	127.0.0.1	NULL		0		0	NULL		0	0	

Creation of account for UJI Member:

The members of the university like the students, faculty, maintenance staff, etc. are required to register to the portal application in order to gain access permission. This process follows the same steps as the case of a visitor, additionally the user needs to specify whether s/he is an academic member or maintenance member of the university and the building to which s/he belongs.

Test Data:

First Name:	AcademicUJI
Date of Birth:	01/01/1990
Gender	Female
Email Address	AcademicUJI@uji.es
University Role	UJIAcademic
Location/ Building	UB

Test Steps:

1. We click on the link “Create Account”

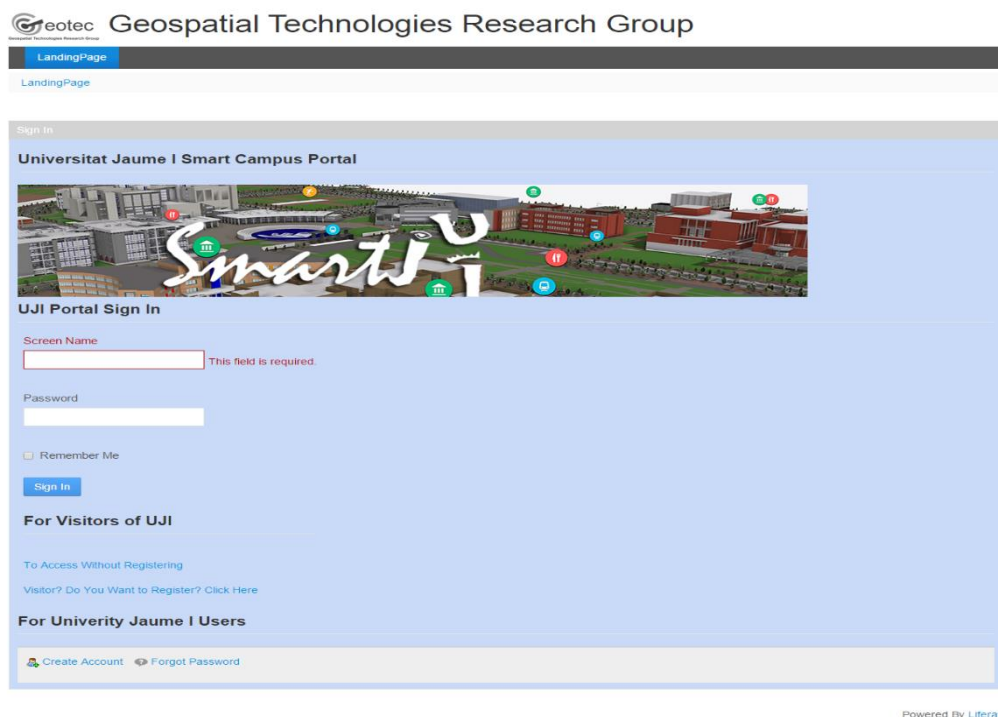


Figure d: Login page with the link to register for UJI Members

2. We will fill the form in the create account page with the details of the UJI member and click on the “Save” button.

Geotec Geospatial Technologies Research Group

LandingPage

Create Account [Return to Full Page](#)

First Name (Required)
AcademicUJI

Middle Name

Last Name

Screen Name (Required)
AcademicUJI

Email Address (Required)
AcademicUJI@uji.es

Birthday
01/01/1990

Userrole
UJIAcademic

Choosebuildingid
UB

Gender
Female

Text Verification (Required)
3185

Save

[Sign In](#) [Forgot Password](#)

Powered By Liferay

Figure e. The details of the UJI member are entered to create an account.

3. Note down the password (highlighted) shown on the screen to login.

Geotec Geospatial Technologies Research Group

LandingPage

Sign In [Return to Full Page](#)

Universitat Jaume I Smart Campus Portal

UJI Portal Sign In

Thank you for creating an account. Your password is **PrU03E**. Your password has been sent to academicuji@uji.es.

Screen Name
academicuji

Password

☐ Remember Me

Sign In

For Visitors of UJI

To Access Without Registering
Visitor? Do You Want to Register? Click Here

For University Jaume I Users

[Create Account](#) [Forgot Password](#)

Powered By Liferay

Figure f: Registration successful and the password is shown

Validation: We checked in the database whether the user account is created. The result is shown below with UserID of 20122.

```
mysql> select * from user_ where firstName="AcademicUJI";
```

uuid_	userId	companyId	createDate	modifiedDate	defaultUser	contactId	password_	passwordEncrypted	passwordReset	passwordModifiedDate	digest	reminderQueryQuestion	reminderQueryAnswer	graceLoginCount	screenName	emailAddress	facebookId	ldapServerId	openId	portraitId	languageId	timeZoneId	greeting	comments	firstName	middleName	lastName	jobTitle	loginDate	loginIP	lastLoginDate	lastLoginIP	lastFailedLoginDate	failedLoginAttempts	lockout	lockoutDate	agreedToTermsOfUse	emailAddressVerified	status		
616ac333-716c-4291-b0a6-0ca512f598b0	20122	10157	2015-02-11 12:41:11	2015-02-11 12:41:11	0	20123	AAAAoAAB9AA7XDT4IfUwISOB8ptbMpYM5kMHDggtFZj7RlRh	1	1	2015-02-11 12:41:11				0	academicuji	academicuji@uji.es	0	-1		0	en_US	Europe/Paris	Welcome AcademicUJI!		AcademicUJI				NULL		NULL		NULL		0	0	NULL		0	0	0

Logging into Prototype Application:

After the creation of the application, the user now logs into the application. There are two scenarios in which the user logs into the system: first-time login and normal login. In the case of the normal login, we just enter the credentials screenname and password. If it's correct, we would directly access the application, otherwise we would be instructed to retry. In the case of first-time login, we would first ask the user to agree the terms of use that includes the clause that the user's location information would be used for administrative purposes (see figure). Upon agreeing to the terms of use, the user would be directed to change his/her password. The user sets a password to his liking and clicks on the "Next" button. The user will be requested to set a security question that will be used to reset the password in the future. After setting the security question, the user will click on "Next" button upon which s/he will be directed to the landing page of the prototype application.

Normal Login:

Test Data:

ScreenName	Abc1
Password	abc1

Test Steps:

1. Enter the login details in the login page and click on “Sign In” button.

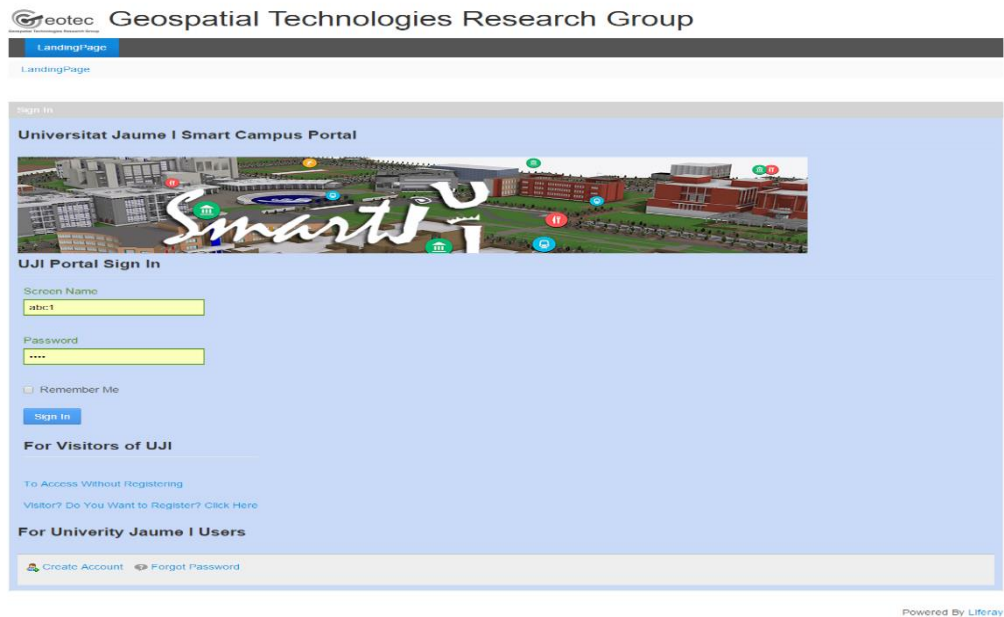


Figure g: User's credentials are entered in the Login page

2. The credentials are correct and we will access the landing page of the portal application.



Figure h: The Landing Page of the user

First time Login:

Test Data:

We use the account details created in “Create Account for UJI member” test.

Screenname	AcademicUJI
------------	-------------

Test Steps:

1. Use the password displayed on the screen once, the registration is completed and click on “Sign In” button.

Geotec Geospatial Technologies Research Group

LandingPage

Sign In

Return to Full Page

Universitat Jaume I Smart Campus Portal

SmartUJI

UJI Portal Sign In

Thank you for creating an account. Your password is PrU03S. Your password has been sent to academicuji@uji.es.

Screen Name

academicuji

Password

PrU03S

☐ Remember Me

Sign In

For Visitors of UJI

To Access Without Registering

Visitor? Do You Want to Register? Click Here


For Univerity Jaume I Users

Create Account Forgot Password

Powered By Liferay

Figure i: First time login to the application

2. Agree to the terms of use clause. Note that the Location information will be utilized by the application clause is highlighted.

 Geospatial Technologies Research Group

LandingPage

LandingPage

Terms of Use

Welcome to ULL Smart Campus Portal Application. We maintain this web site as a service to members and visitors of University Jaume I. By using our site, you are agreeing to comply with and be bound by the following terms of use. Please review the following terms carefully. If you do not agree to these terms, you should not use this site.

- Acceptance of Agreement**

You agree to the terms and conditions outlined in this Terms of Use Agreement ("Agreement") with respect to our site (the "Site"). This Agreement constitutes the entire and only agreement between us and you, and supersedes all prior or contemporaneous agreements, representations, warranties and understandings with respect to the Site, the content, products or services provided by or through the Site, and the subject matter of this Agreement. This Agreement may be amended at any time by us from time to time without specific notice to you. The latest Agreement will be posted on the Site, and you should review this Agreement prior to using the Site.
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We reserve the right, and you authorize us, to the use and assignment of all information regarding Site uses by you and all information provided by you in any manner consistent with our Privacy Policy. All remarks, suggestions, ideas, graphics, or other information communicated by you to us through the Site (collectively, the "Submission") will forever be the property of Geospatial Technologies Research Group. Geospatial Technologies Research Group will not be required to treat any Submission as confidential, and will not be liable for any ideas for its business (including without limitation, product, service or advertising ideas) and will not incur any liability as a result of any similarities that may appear in future Geospatial Technologies Research Group products, services or operations. Without limitation, Geospatial Technologies Research Group will have exclusive ownership of all present and future existing rights to the Submission of every kind and nature everywhere. Geospatial Technologies Research Group will be entitled to use the Submission for any commercial or other purpose whatsoever, without compensation to you or any other person sending the Submission. You acknowledge that you are responsible for whatever material you submit, and you, not Geospatial Technologies Research Group, have full responsibility for the message, including its legality, reliability, appropriateness, originality, and copyright.
- Location Information**

We utilize the location information captured from your device for performing analytics. By agreeing to this terms you express your interest to share your location in order to access the portal application.
- Privacy Policy**

Our Privacy Policy, as it may change from time to time, is a part of this Agreement.
- Securities Laws**

This Site may include statements concerning our operations, prospects, strategies, financial condition, future economic performance and demand for our products or services, as well as our intentions, plans and objectives (particularly with respect to product and service offerings), that are forward-looking statements. These statements are based upon a number of assumptions and estimates which are subject to significant uncertainties, many of which are beyond our control. When used on our Site, words like "anticipates," "expects," "believes," "estimates," "seeks," "plans," "intends," "will" and similar expressions are intended to identify forward-looking statements designed to fall within securities law safe harbors for forward-looking statements. The Site and the information contained herein does not constitute an offer or a solicitation of an offer for sale of any securities. None of the information contained herein is intended to be, and shall not be deemed to be, incorporated into any of our securities-related filings or documents.
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The Site contains links to other web sites. We are not responsible for the content, accuracy or opinions express in such web sites, and such web sites are not investigated, monitored or checked for accuracy or completeness by us. Inclusion of any linked web site on our Site does not imply approval or endorsement of the linked web site by us. If you decide to leave our Site and access these third-party sites, you do so at your own risk.
- Copyrights and Copyright Agents**

We respect the intellectual property of others, and we ask you to do the same. If you believe that your work has been copied in a way that constitutes copyright infringement, please provide our Copyright Agent the following information:

 - An electronic or physical signature of the person authorized to act on behalf of the owner of the copyright interest;
 - A description of the copyrighted work that you claim has been infringed;
 - A description of where the material that you claim is infringing is located on the Site;
 - Your address, telephone number, and email address;
 - A statement by you that you have a good faith belief that the disputed use is not authorized by the copyright owner, its agent, or the law; and
 - A statement by you, made under penalty of perjury, that the above information in your Notice is accurate and that you are the copyright owner or authorized to act on the copyright owner's behalf. Our Copyright Agent for Notice of claims of copyright infringement on the Site can be reached by directing an e-mail to the Copyright Agent at admin@up.es.
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I Agree

I Disagree

Powered By Literay

Figure j: The terms of Use clauses of the portal application

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3. The user changes his/her password to a new password. In this case, we change it to “abc1” and click on “Save” button.

The screenshot shows the Geotec Geospatial Technologies Research Group website. The header includes the logo and the text "Geotec Geospatial Technologies Research Group". Below the header, there is a navigation bar with "LandingPage" and a link to "LandingPage". The main content area is titled "New Password" and contains a light blue box with the text "Please set a new password." Below this, the form is titled "New Password" and has two input fields: "Password" and "Enter Again", both containing four asterisks. A "Save" button is at the bottom. The footer text "Powered By Liferay" is visible.

Figure k: resetting password of the user

4. We will set a security question for the password. In this case, we set the father’s name to “madhav” and click on “Save” button.

The screenshot shows the Geotec Geospatial Technologies Research Group website. The header includes the logo and the text "Geotec Geospatial Technologies Research Group". Below the header, there is a navigation bar with "LandingPage" and a link to "LandingPage". The main content area is titled "Password Reminder" and contains a light blue box with the text "Please choose a reminder query." Below this, the form is titled "Password Reminder" and has a "Question" dropdown menu with the text "What is your father's middle name?". Below the dropdown is an "Answer" input field containing the text "madhav". A "Save" button is at the bottom. The footer text "Powered By Liferay" is visible.

Figure l: Setting a security question.

5. We will access the portal application with content specific to UJI Academic User group and “UB” building.

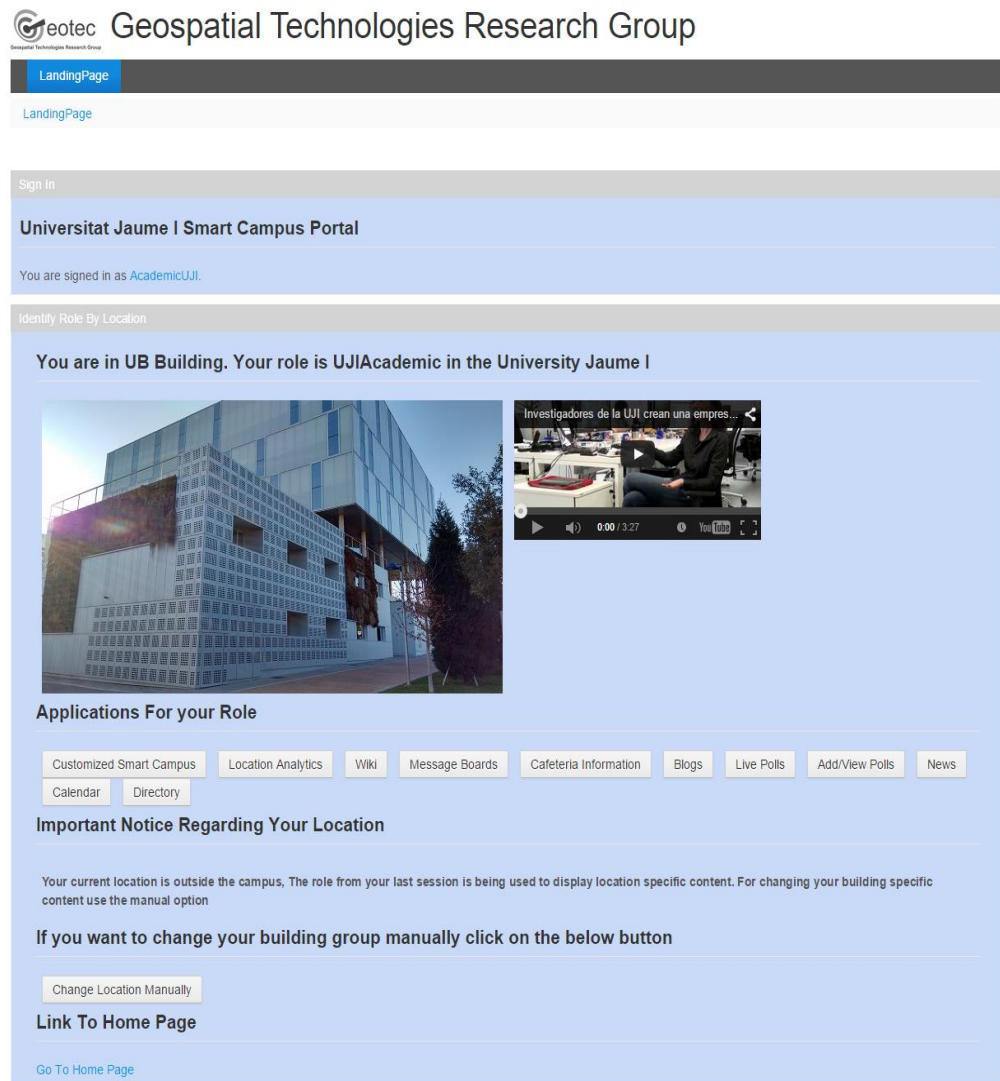


Figure m: Landing Page for the user.

Assignment of Location-specific role based on User's Physical Location:

The user's physical location would be monitored every 60 seconds, if there is any change in the user's physical location and the new position corresponds to one of the chosen buildings, then we ask the user to change his/her role.

Test Data:

We use the user "AcademicUJI" profile to perform this test. The new location corresponds to "CD" building and initial location-specific role is "UB".

Initial Condition: The system detected the location of the user and proposes to the user to change the role according to the new location "CD" building.

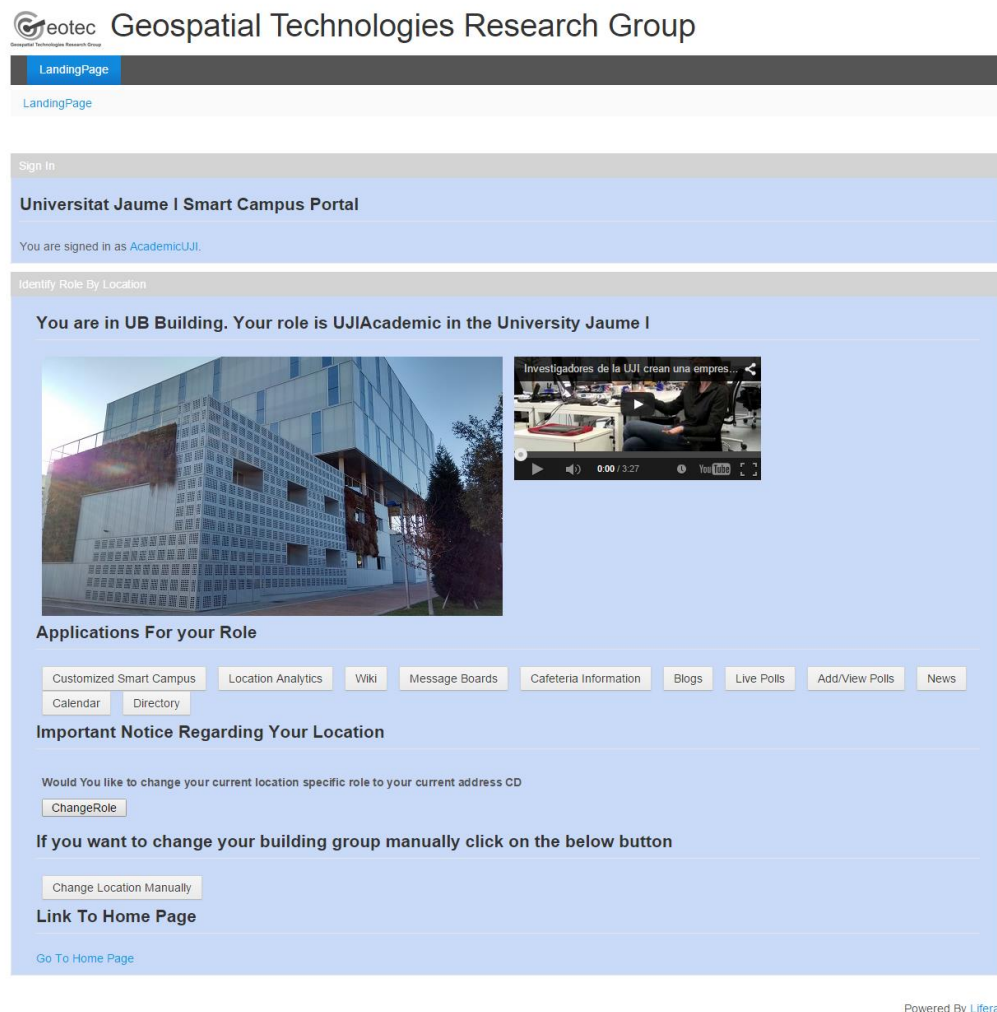


Figure n: The user's Physical Location is different to location-specific role.

The user then decides to click on the “change role” button. Upon which, the user’s location-specific role will be changed to “CD”, and the content and behavior would change accordingly.

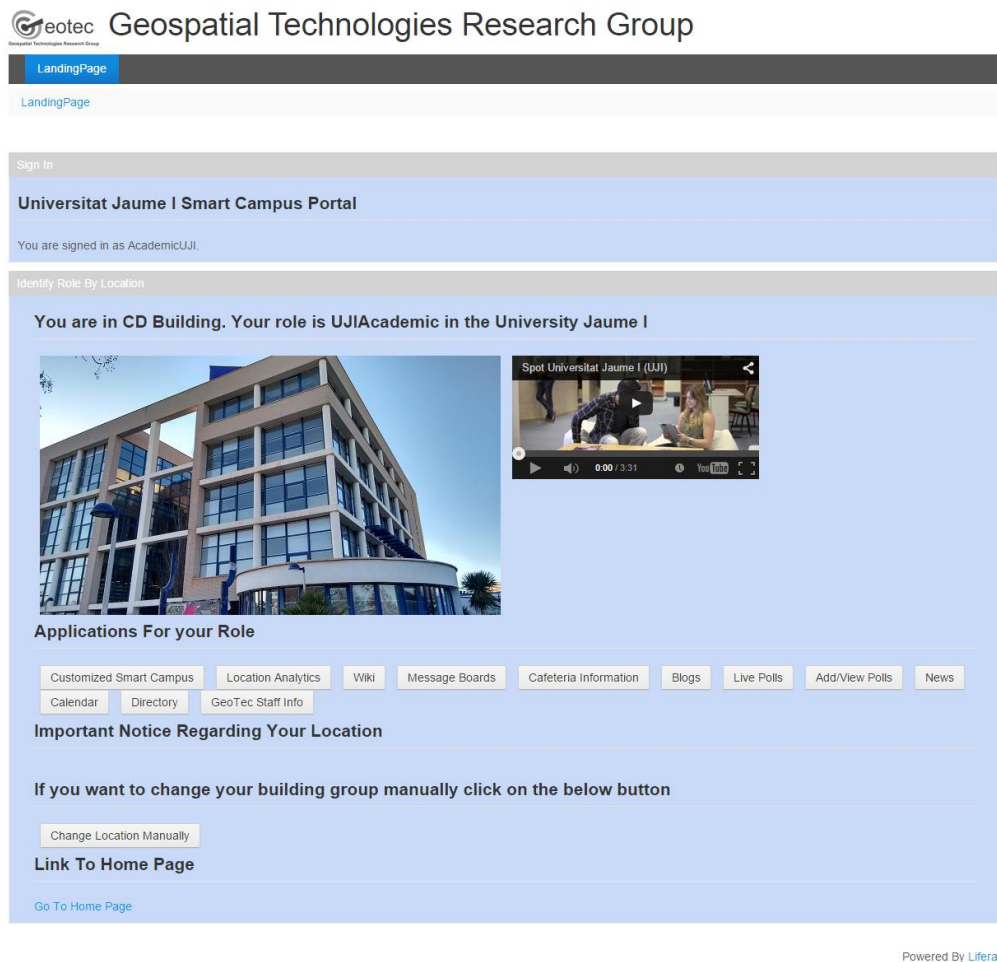


Figure o: After the role change, the user’s landing page content is changed

Manual Location-Specific Role Change:

As discussed in the prototype chapter we can modify our location-specific role by using the manual option. In this test, we will modify the location-specific role of “AcademicUJI” user from “CD” to “TD”.

Test Steps:

1. Click on the “Change Location Manually” button on the user’s landing page.

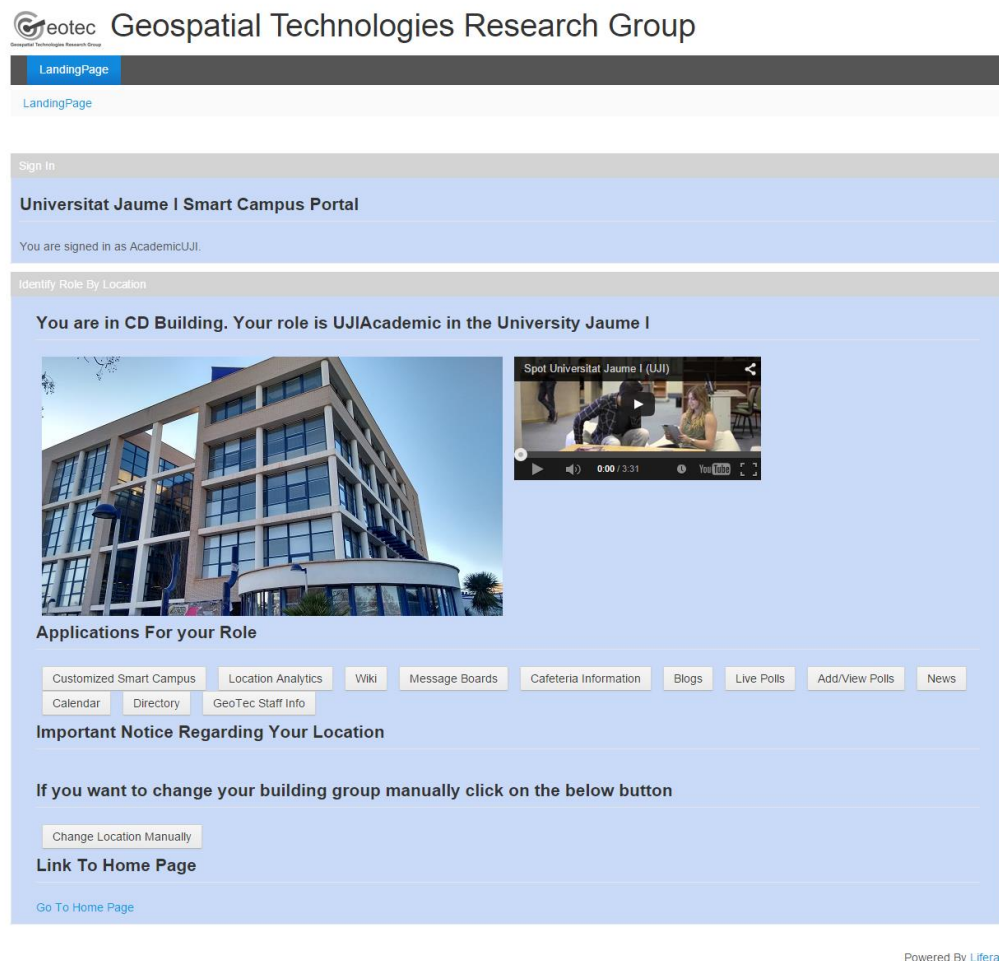


Figure p: “Change Location Manually” button is selected.

2. Click on the building “TD” on the map as shown in the below figure.



Figure q: The Manual Change Option Page of the Prototype application

3. The User's role is now changed to “TD” building.

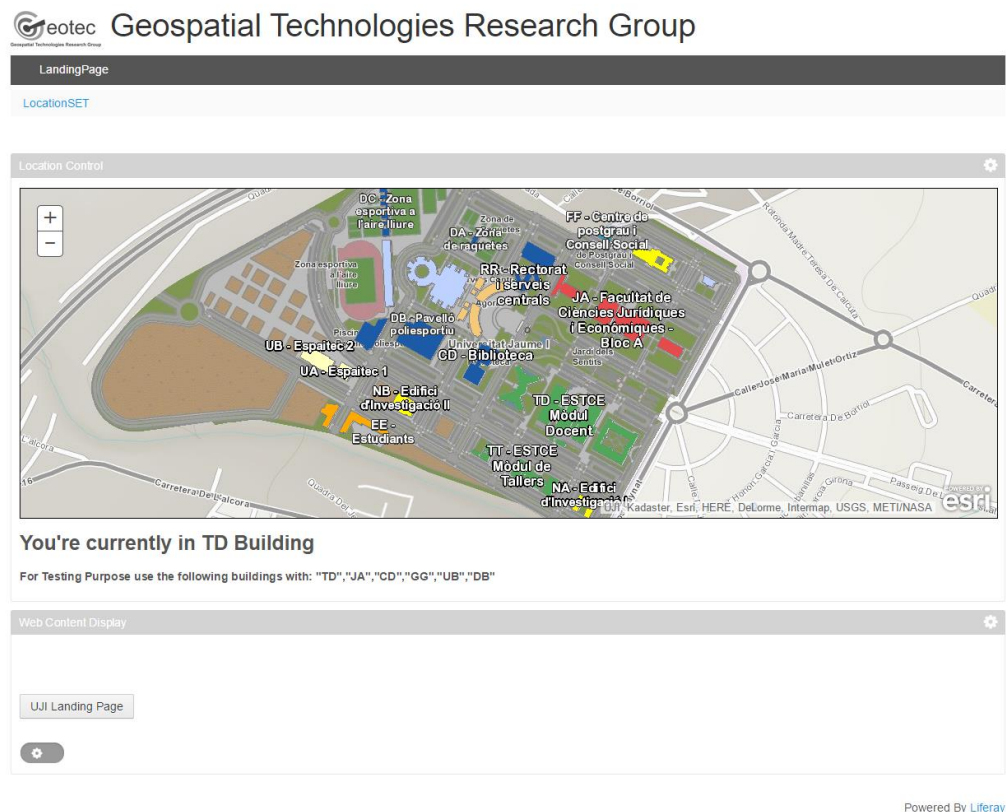


Figure r: The role changed to “TD”

4. The User landing page content is changed according to the new location-specific role.

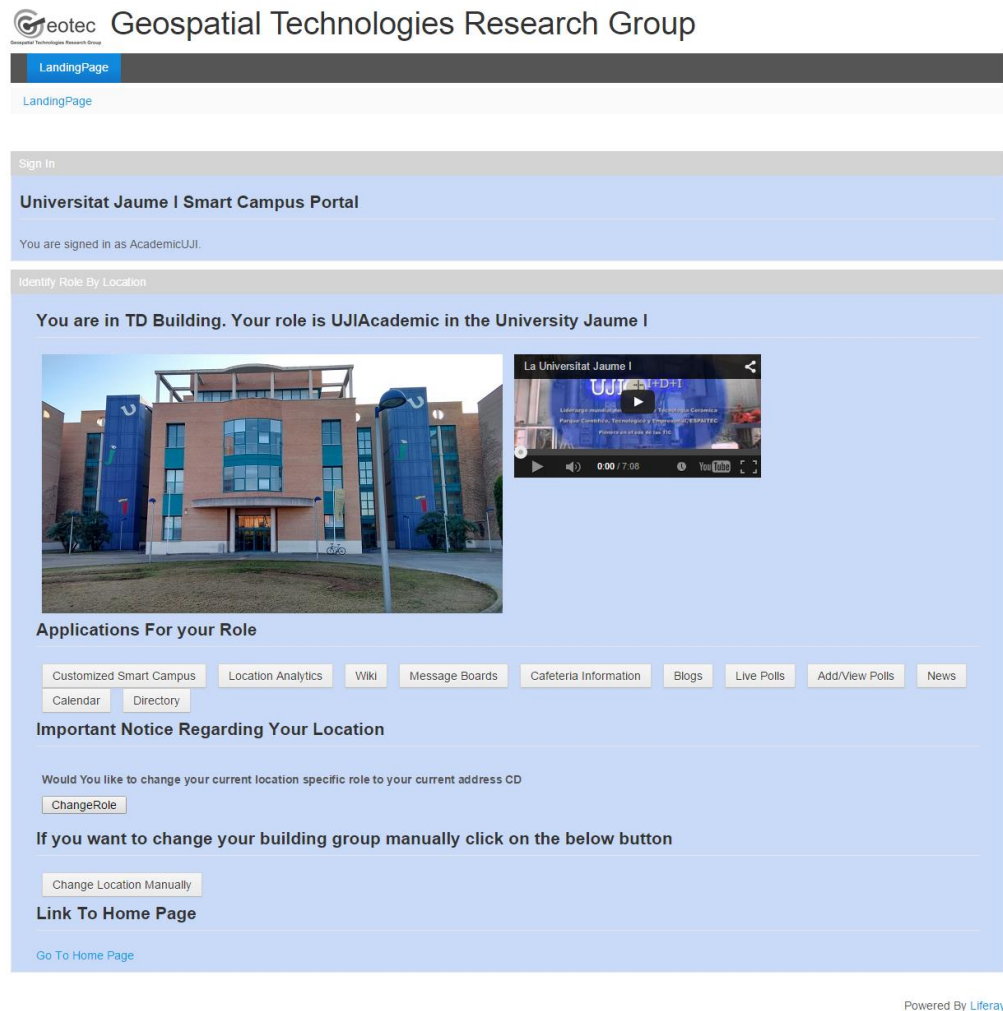


Figure s: The landing page with role “TD”.

Location Analytics Application Tests

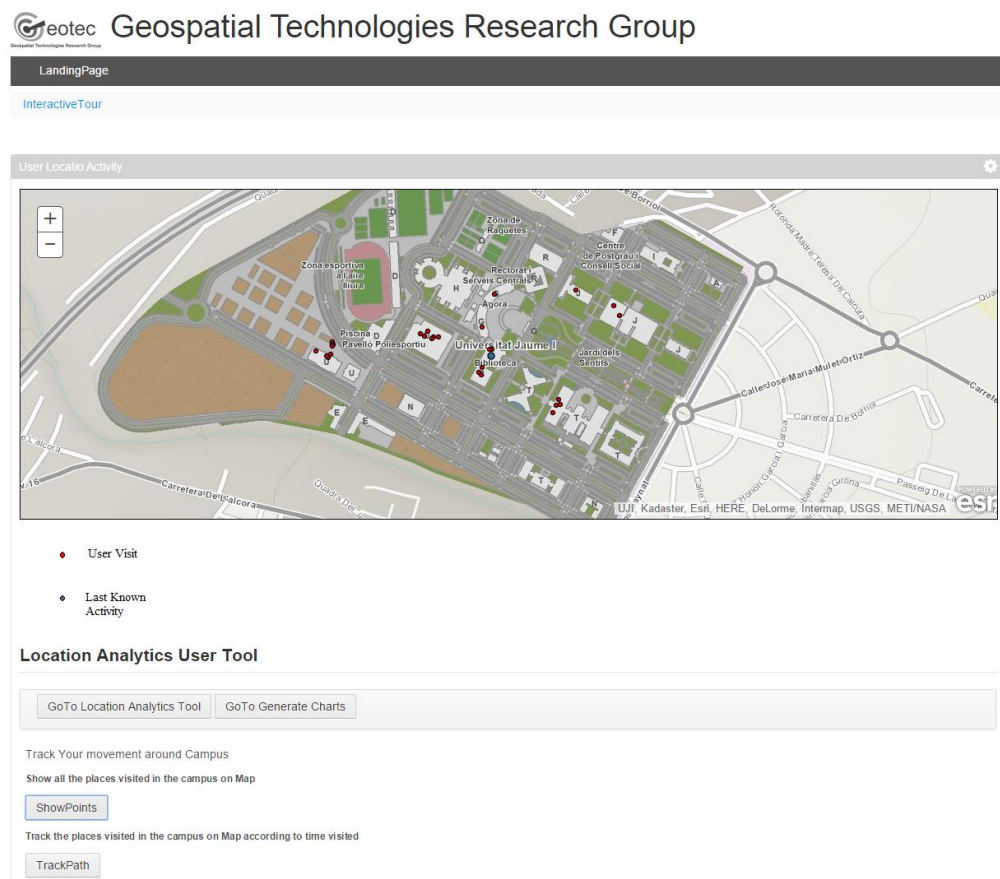
Apart from the tests for the Smart-RBAC model, we performed tests on the subsidiary application of the Smart-RBAC model, i.e. Location Analytics Application.

Considering the number of scenarios, we just describe the screenshots, instead of explaining each scenario in detail. The main perspectives of this application are:
Normal user and Administrator.

Normal User Perspective:

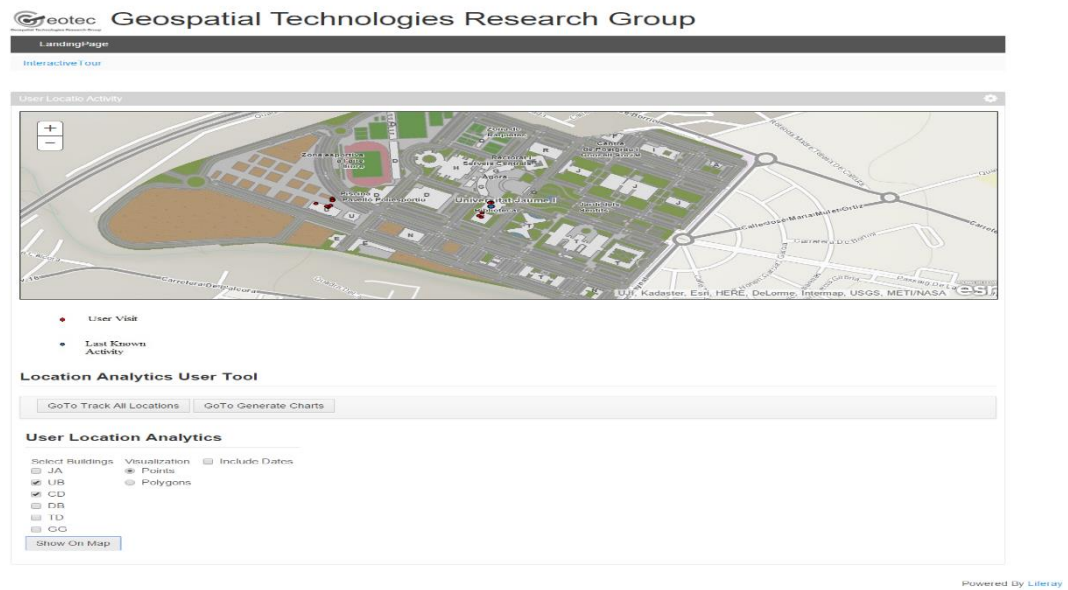
The test user is “abc1”. The normal user scenarios are:

- Historical data of all the visits of the user

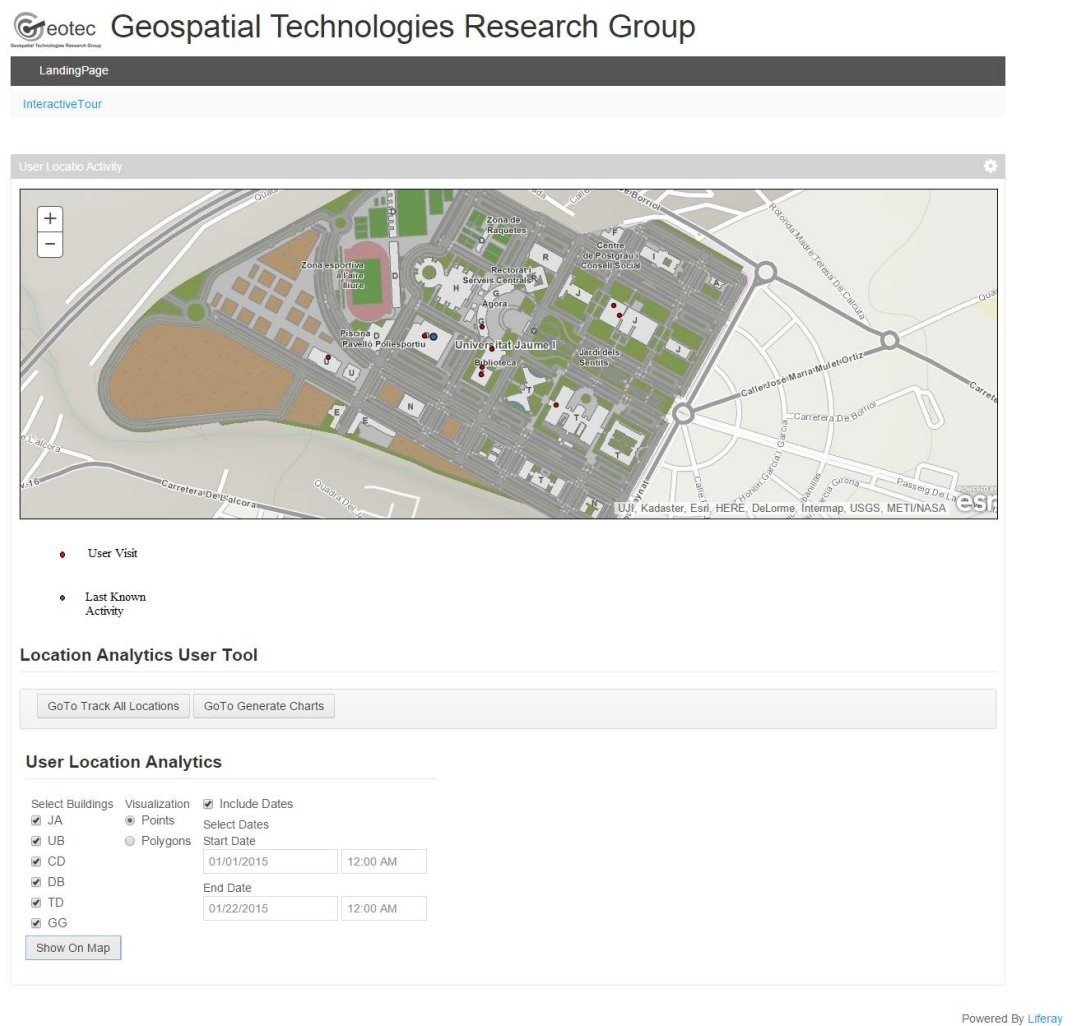


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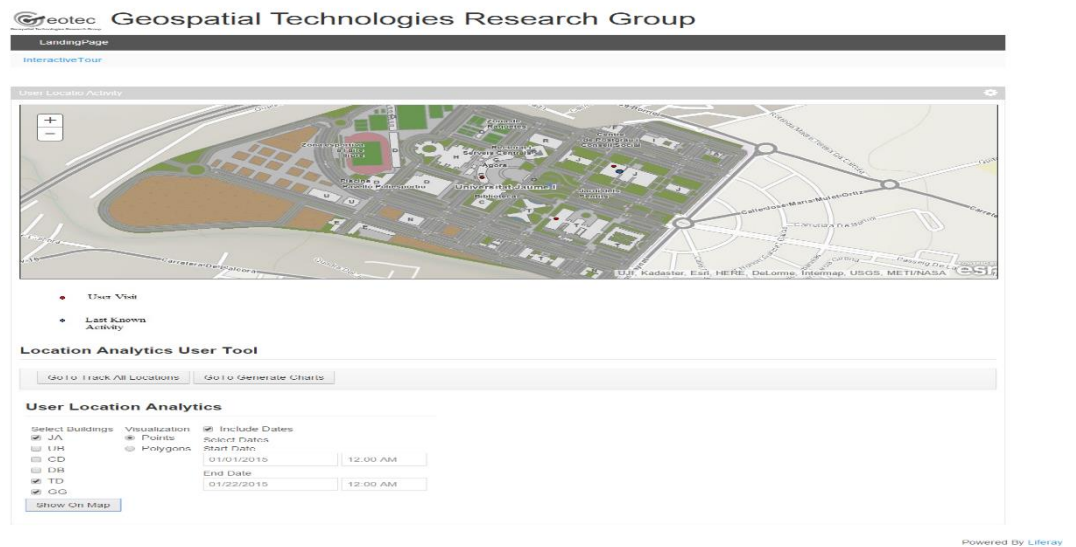
- Historical data of user visits to selected buildings



- Data of all the visits during the selected time period

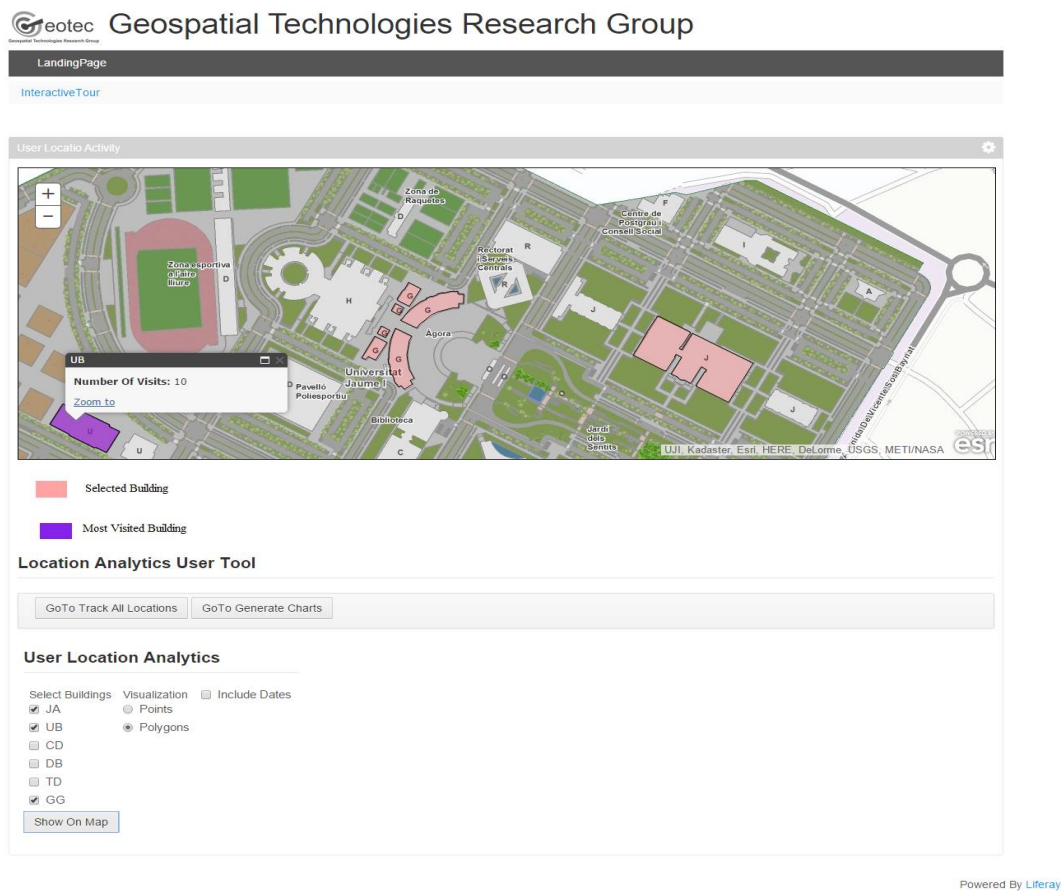


- Data of user visits to selected buildings during the selected time period



Outcomes Visualized as polygons on Map:

Historical data about the number of visits to the selected buildings

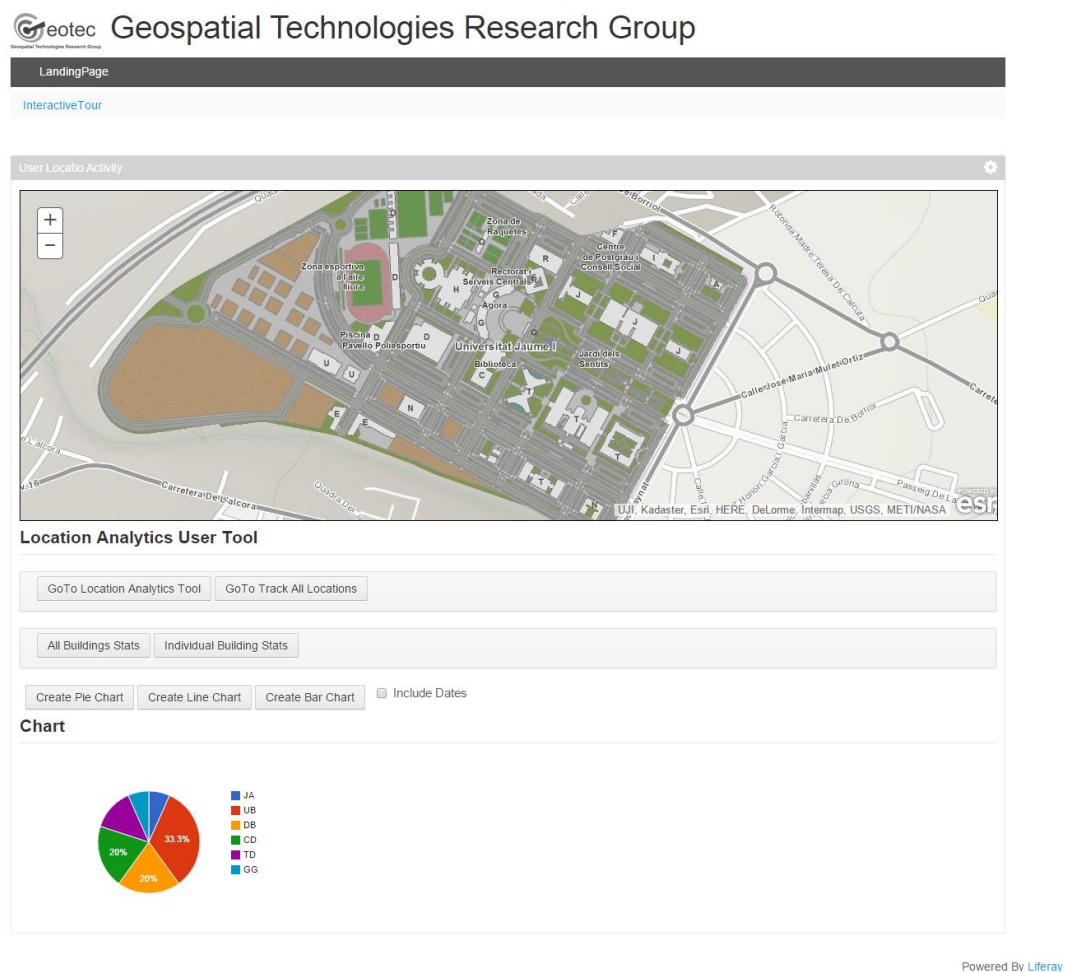


- Data about the number of visits to selected buildings during specific time period



Outcomes Visualized as charts:

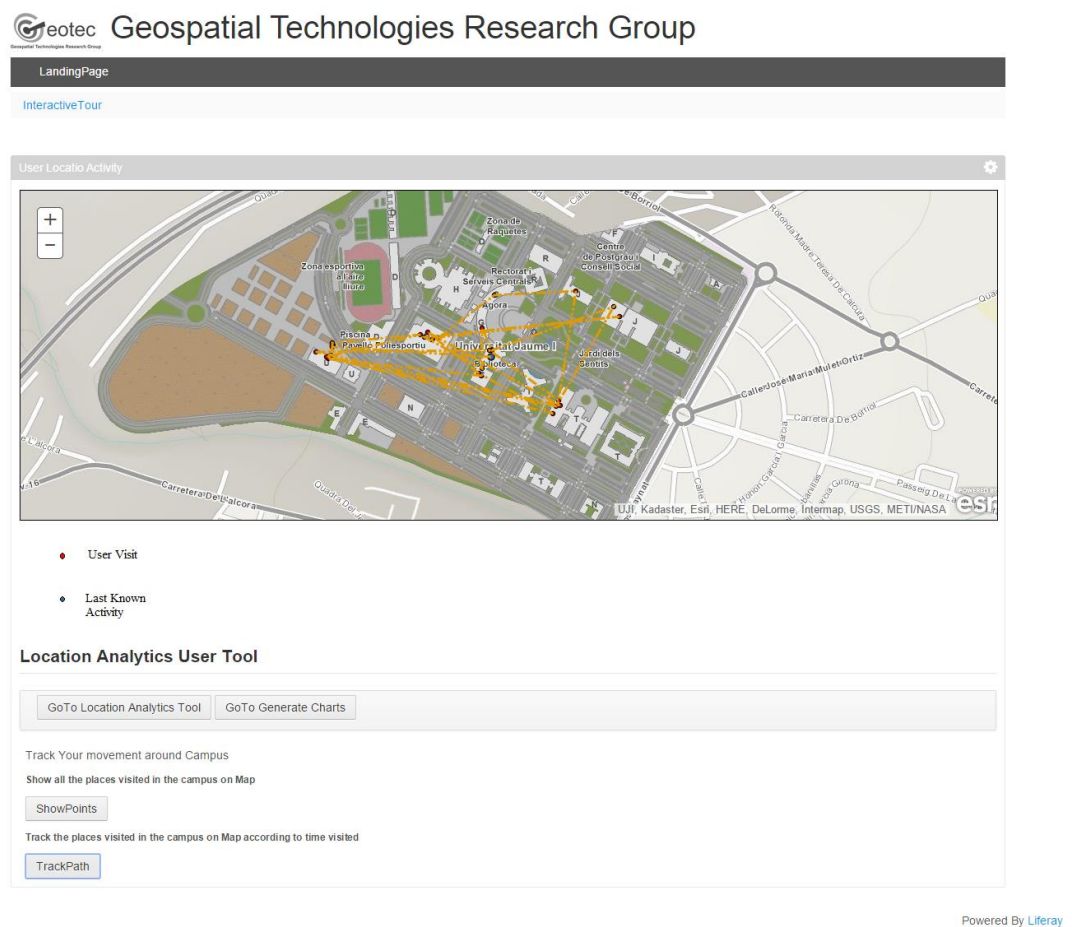
- Number of visits to different buildings



- Number of visits to different buildings during selected time period.



Additional Outcomes: The users' visits on the map are tracked with line feature according to the timestamp of each visit.



Administrator:

Outcomes Visualized as points on Map:

- Historical data of all the visits of all the users



- Historical data of selected user visits to selected buildings



- Data of all the visits of selected type of users to selected buildings



- Data of all the visits of selected type of users during the selected time period

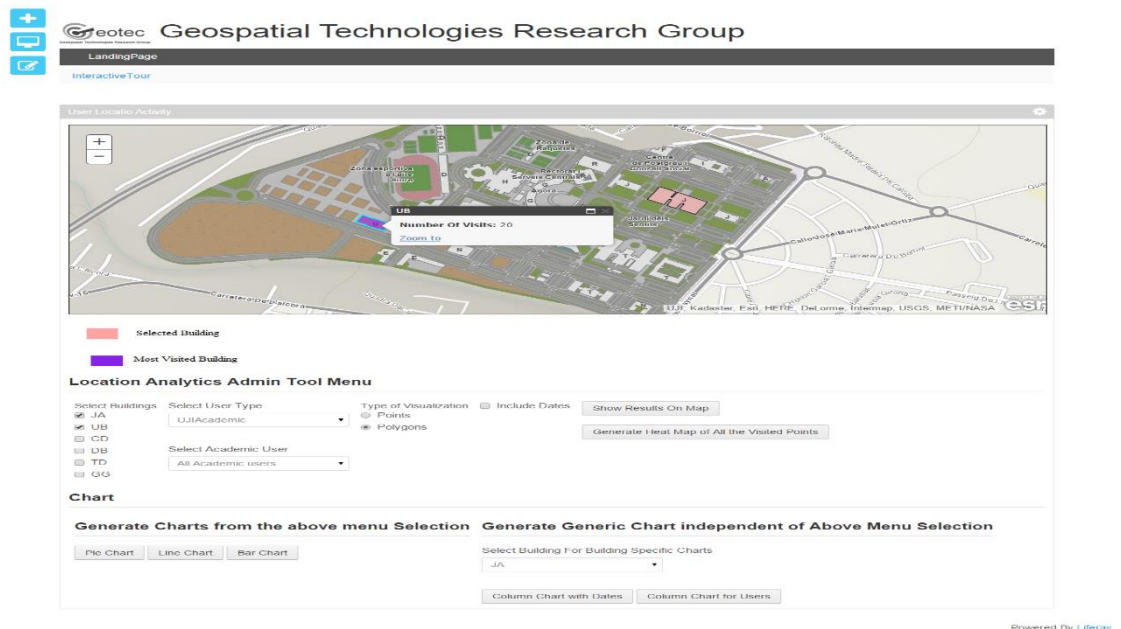


- Data of selected user visits to selected buildings during the selected time period

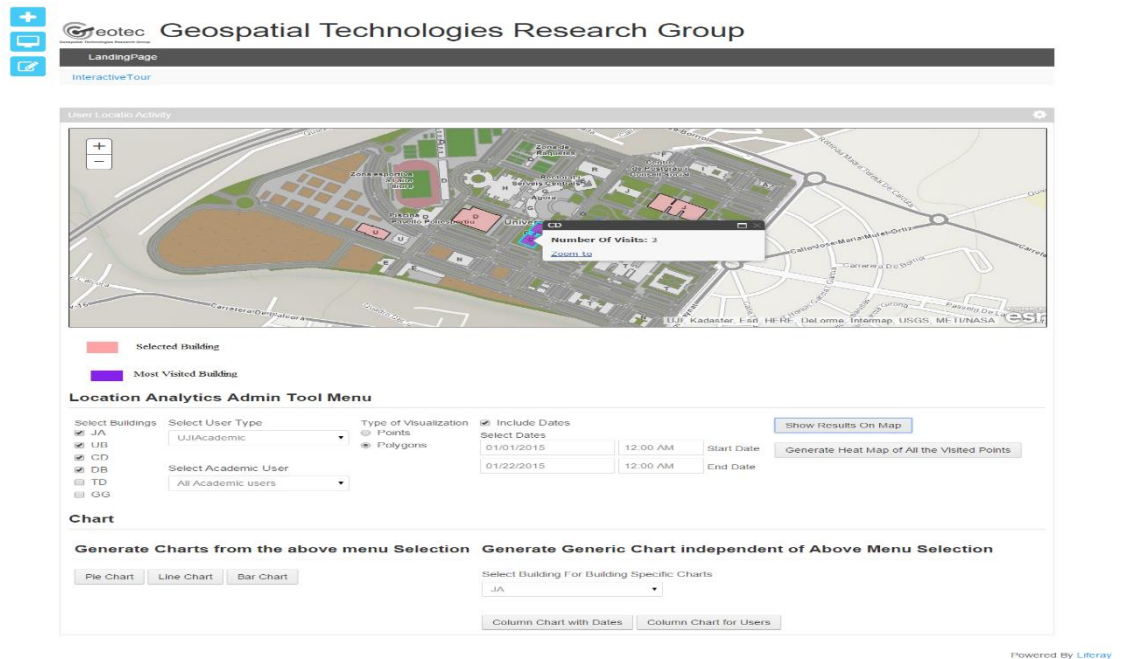


Outcomes Visualized as polygons on Map:

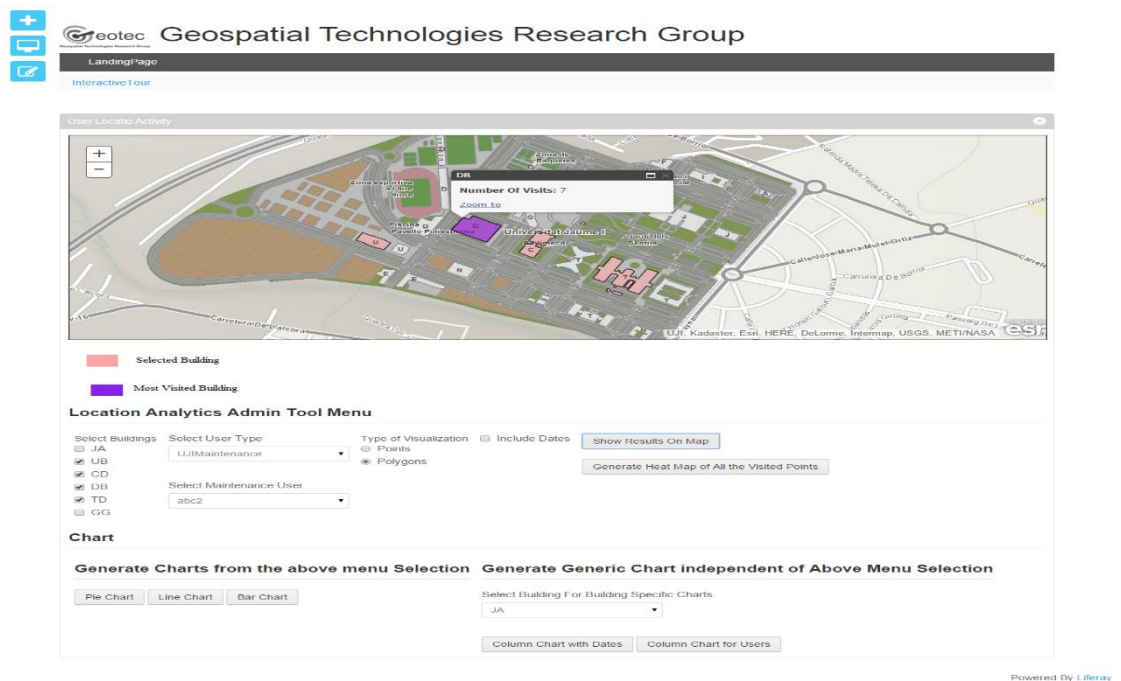
- Historical data about the number of visits to the selected buildings of selected user type



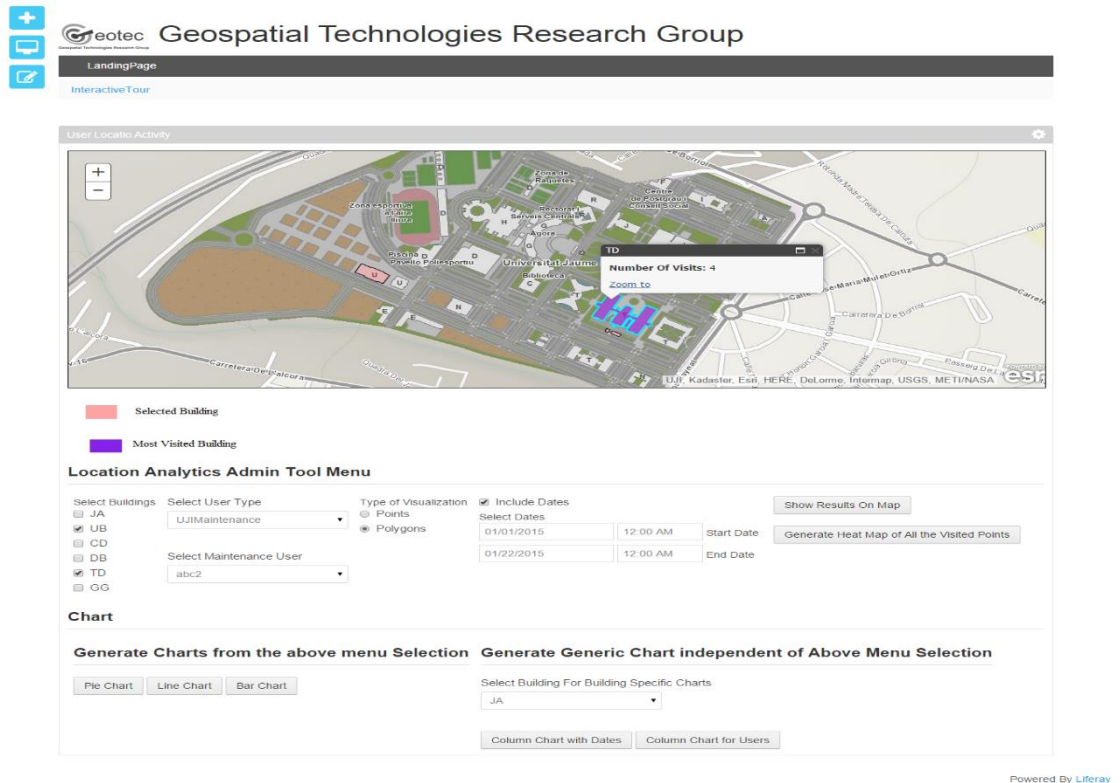
- Data about the number of visits to selected buildings of selected user type during specific time period



- Historical data about the number of visits to the selected buildings of selected user

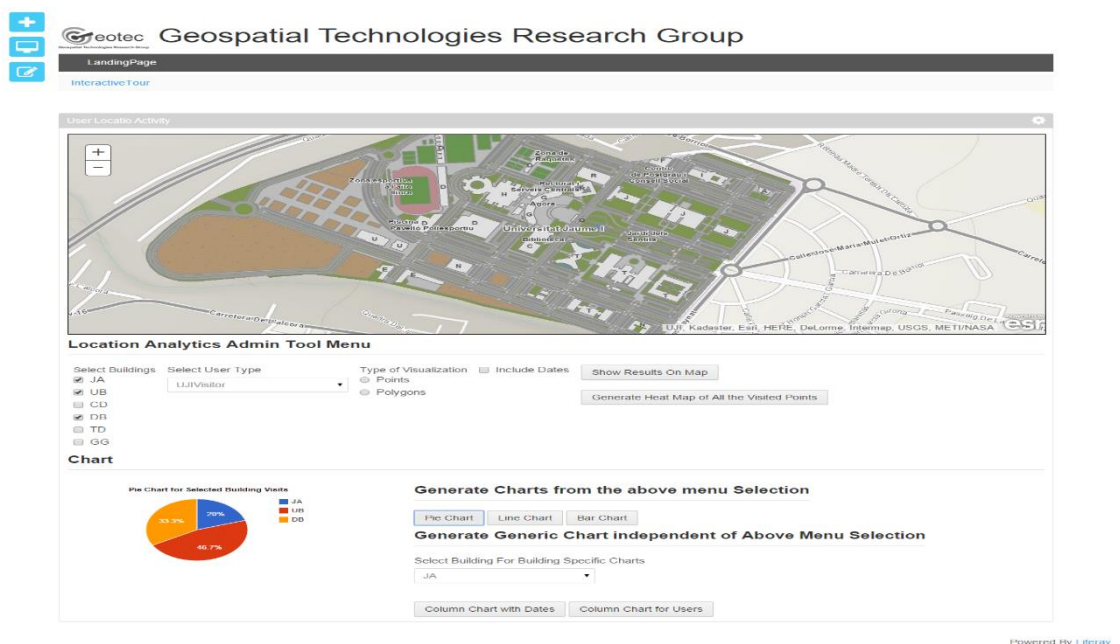


- Data about the number of visits to selected buildings of selected user during specific time period



Outcomes Visualized as charts:

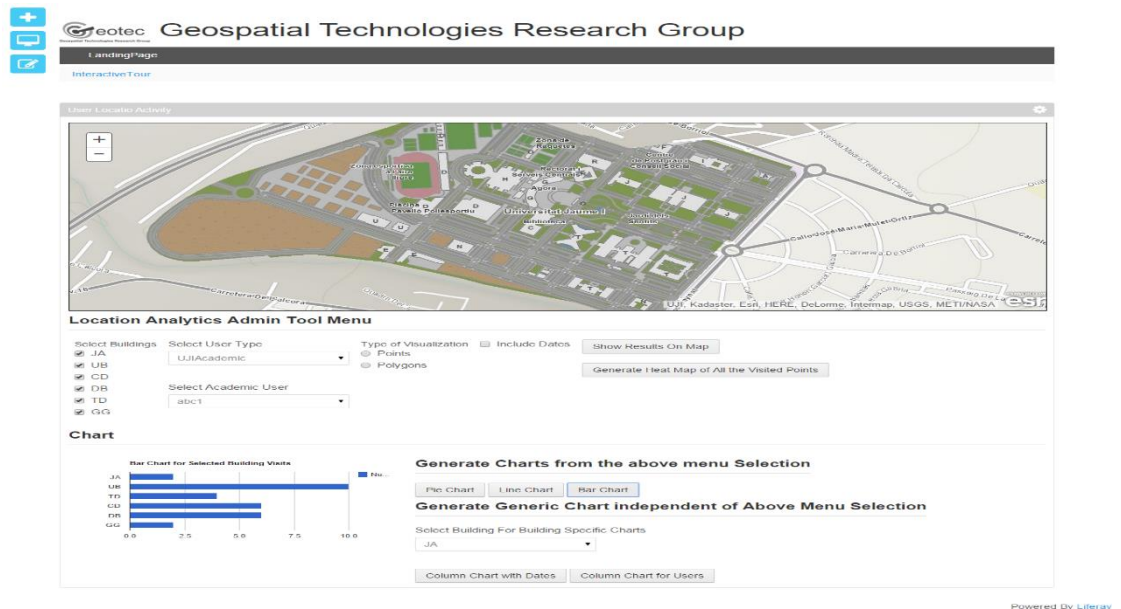
- Historical data about the number of visits to the selected buildings of selected user type



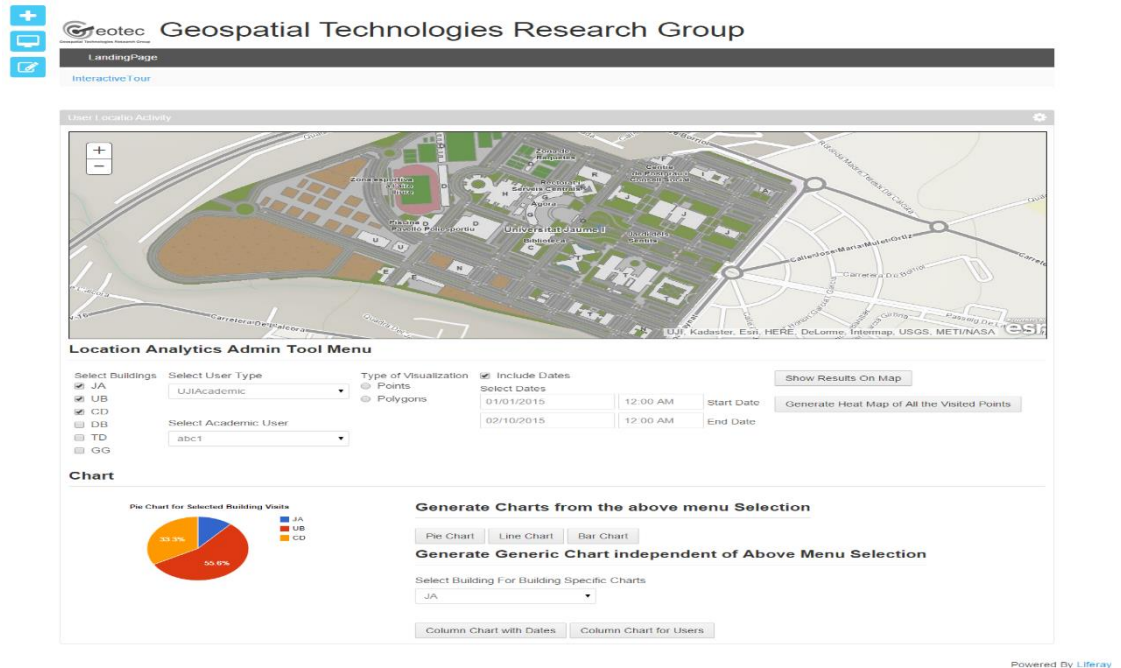
- Data about the number of visits to selected buildings of selected user type during specific time period



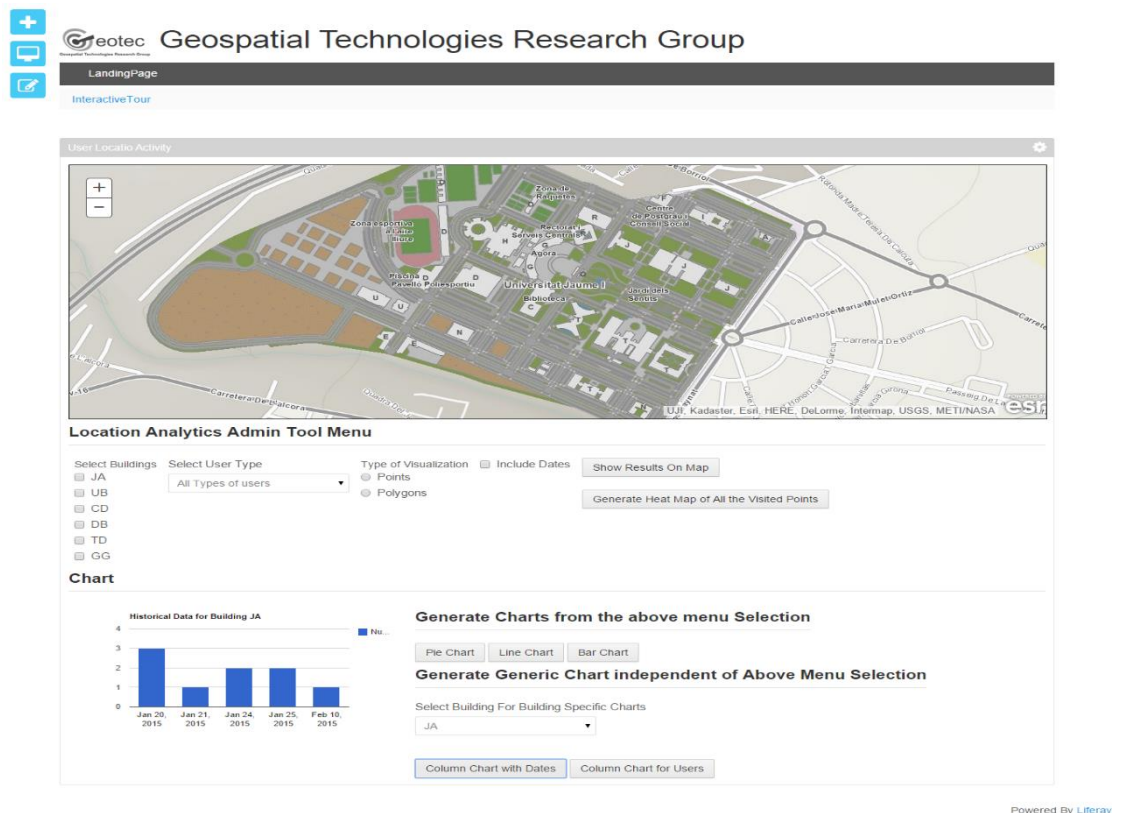
- Historical data about the number of visits to the selected buildings of selected user



- Data about the number of visits to selected buildings of selected user during specific time period



- Column charts for number of visits against the date of visits for all users with regard to a selected building.

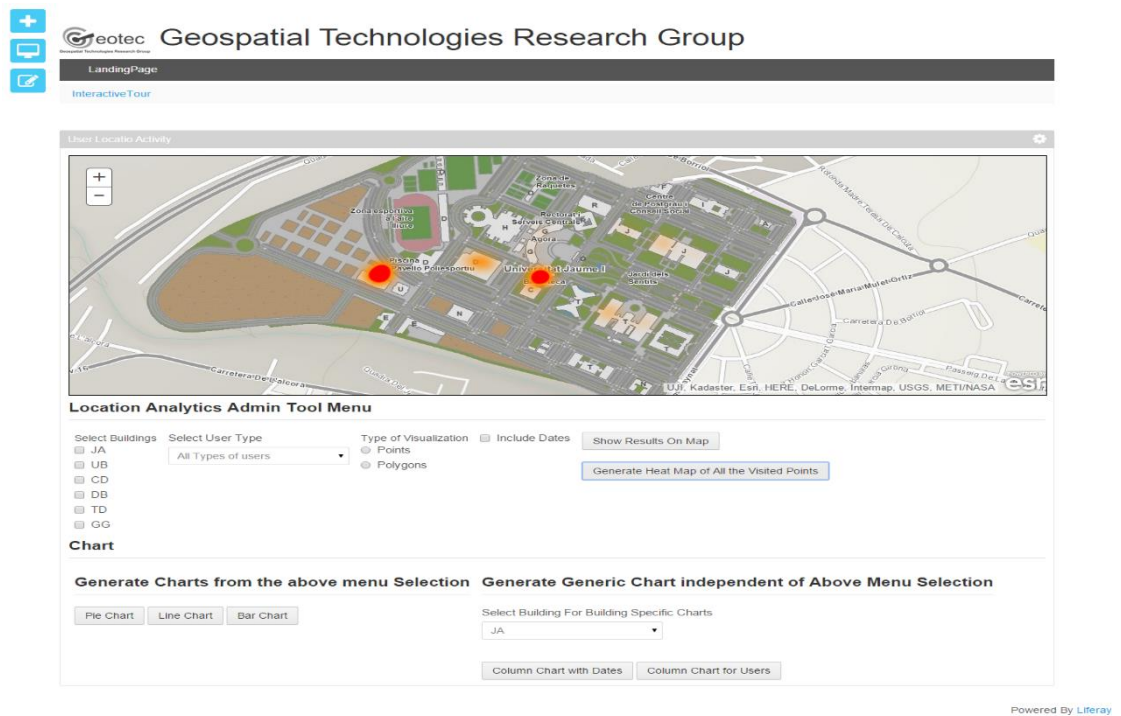


- Column Chart regarding number of visits by each user for a selected building.



Additional Outcomes:

- Heat Map displaying the density of all the visits on the map



Appendix B: Application Code

We developed five portlet plugin projects and two custom hooks as per part of the UJI Smart Campus Portal Application. The plugin and hook Projects are:

- IdentifyRolebyLocation-portlet
- LocationControl-portlet
- SmartCampusOrganizationRole-portlet
- UJILoginPortlet-hook
- CustomPolls-hook
- UJIPollsPortlet-portlet
- UserLocatioActivity-portlet

The code is present in the following location:

<https://github.com/Bhuvangsr/UJI-Smart-Campus-Portal>

Apart from these projects we had created web content in the Liferay Portal server regarding the cafeteria information, GeoTec staff information in “UB” building, etc.

The links for the Smart UJI Campus services are listed below:

1. Buildings:
[http://smartcampus.sg.uji.es:6080/arcgis/rest/services/SmartCampus/B
uildingsNew/MapServer](http://smartcampus.sg.uji.es:6080/arcgis/rest/services/SmartCampus/BuildingsNew/MapServer)
2. User Location:
[http://services1.arcgis.com/k8WRSCmxGgCwZufI/ArcGIS/rest/services/Use
rLocationTracking/FeatureServer/0](http://services1.arcgis.com/k8WRSCmxGgCwZufI/ArcGIS/rest/services/UserLocationTracking/FeatureServer/0)
3. Geometry Server:
[http://smart.uji.es/adaptor/rest/services/Utilities/Geometry/Geometry
Server](http://smart.uji.es/adaptor/rest/services/Utilities/Geometry/GeometryServer)
4. Energy Consumption:
[http://smart.uji.es/adaptor/rest/services/Energy/Resources_Consumptio
n/MapServer](http://smart.uji.es/adaptor/rest/services/Energy/Resources_Consumption/MapServer)
5. Facilities:
[http://smart.uji.es/adaptor/rest/services/SmartCampus/Facilities_by_f
loor/MapServer/](http://smart.uji.es/adaptor/rest/services/SmartCampus/Facilities_by_floor/MapServer/)

Masters Program in **Geospatial Technologies**



Smart-RBAC: A Location-based Access Control Model for Location-specific Content Delivery and Analytics in a Smart Campus

Srinivasa Raghavendra Bhuvan Gummidi

Dissertation submitted in partial fulfilment of the requirements
for the Degree of *Master of Science in Geospatial Technologies*

2015

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Masters Program in **Geospatial Technologies**

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